

Motorcoach Collision
With Crash Attenuator in Gore Area
US Highway 101
San Jose, California
January 19, 2016



Accident Report

NTSB/HAR-17/01
PB2017-101430



**National
Transportation
Safety Board**

Highway Accident Report

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**National
Transportation
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490 L'Enfant Plaza SW
Washington, DC 20594

National Transportation Safety Board. 2017. *Motorcoach Collision With Crash Attenuator in Gore Area, US Highway 101, San Jose, California, January 19, 2016*. Highway Accident Report NTSB/HAR-17/01. Washington, DC.

Abstract: On January 19, 2016, about 6:37 a.m., a 2014 Motor Coach Industries International, Inc. (MCI), D4505 motorcoach, operated by Greyhound Lines, Inc., was traveling northbound on US Highway 101 (US-101) in San Jose, Santa Clara County, California, when it entered and traveled in an unmarked gore area, rather than the intended high-occupancy-vehicle (HOV) lane, and collided with a crash attenuator. The 990-foot-long gore, with an unmarked inside area, separates the left exit HOV lane for State Route 85 from the US-101 HOV lane. The gore widens to about 22 feet at the point where a nine-cylinder crash attenuator is in place. The attenuator was missing its retroreflective object marker. The bus was occupied by the 58-year-old driver and 21 passengers. As a result of the crash, two of the bus passengers died, and several others were injured. This investigation identified the following safety issues: highway, driver risk management, occupant protection, and collision avoidance systems. The NTSB made new recommendations to the Federal Highway Administration, the California Department of Transportation, the American Bus Association, the United Motorcoach Association, and Greyhound Lines, Inc. In addition, the NTSB reiterated recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the state of California, and MCI.

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Acronyms and Abbreviations

ABA	American Bus Association
AEB	autonomous emergency braking
ASTM	ASTM International
BASIC	behavior analysis and safety improvement category [FMCSA]
Caltrans	California Department of Transportation
CAS	collision avoidance system
CDL	commercial driver's license
CDLIS	Commercial Driver's License Information System
<i>CFR</i>	<i>Code of Federal Regulations</i>
CHP	California Highway Patrol
CR	compliance review
CTBSSP	Commercial Truck and Bus Safety Synthesis Program [TRB]
CVSA	Commercial Vehicle Safety Alliance
CWS	collision warning system
DOT	US Department of Transportation
ECM	engine control module
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
<i>FR</i>	<i>Federal Register</i>
GPS	global positioning system
GVWR	gross vehicle weight rating
HOS	hours-of-service

HOV	high-occupancy-vehicle
IMMS	integrated maintenance management system
MCI	Motor Coach Industries International, Inc.
MCMIS	Motor Carrier Management Information System [FMCSA]
MUTCD	<i>Manual on Uniform Traffic Control Devices for Streets and Highways</i>
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
OOS	out-of-service
PCP	phencyclidine
REACT	reusable energy-absorbing crash terminal
SJFD	San Jose Fire Department
SR-85	State Route 85
THC	delta-9-tetrahydrocannabinol
TL	test level [NCHRP]
TRB	Transportation Research Board
TTC	time to contact
UMA	United Motorcoach Association
US-101	US Highway 101

Executive Summary

Investigation Synopsis

On January 19, 2016, about 6:37 a.m., a 2014 Motor Coach Industries International, Inc., D4505 motorcoach, operated by Greyhound Lines, Inc., and occupied by a driver and 21 passengers, was traveling north on US Highway 101 (US-101), in San Jose, California. The weather conditions were dark, with moderate-to-heavy rain and reported winds from the east–southeast at 20 mph.

At the US-101 and State Route 85 (SR-85) interchange, the bus moved to the left and entered a 990-foot-long unmarked gore area. The gore separates the US-101 lanes from the left exit high-occupancy-vehicle lane for SR-85. A crash attenuator with a missing retroreflective object marker was positioned at the end of the gore in advance of a concrete barrier. The bus driver maintained the vehicle's path through the gore and collided with the crash attenuator and the concrete barrier.

Following the impact, the bus traveled another 65 feet, rolled 90 degrees, and came to rest on its right side atop the concrete barrier, straddling two lanes of traffic. As a result of the crash, two passengers were ejected and died, and the driver and 13 passengers were injured.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the San Jose, California, crash was the failure of the California Department of Transportation to properly delineate the crash attenuator and the gore area, which would have provided improved traffic guidance. Contributing to the crash were the bus driver's error in entering the gore and the out-of-compliance signage, which affected traffic guidance. Contributing to the severity of the injuries was the lack of passenger seat belt use.

The crash investigation focused on the following safety issues:

- **Highway:** The California Department of Transportation did not complete a repair to the damaged crash attenuator, which led to the bus driver's inability to see the forward hazard. Moreover, the unmarked gore and the out-of-compliance signage provided insufficient traffic guidance.
- **Managing driver risk:** Although Greyhound had advanced means of monitoring driver performance, it had no appropriate structure in place to obtain the full benefits of those systems. Furthermore, due to a deficient record-keeping system and correspondingly limited oversight of repeat safety infractions, Greyhound was not adequately managing driver risk.
- **Occupant protection:** The bus was equipped with passenger lap/shoulder belts in all seating positions, but only two passengers wore the restraints. Although Greyhound

has developed a pretrip safety briefing script that includes information about using seat belts, the carrier only recommends that drivers provide the briefing to passengers. Moreover, California's seat belt use laws do not apply to motorcoach passengers—either through primary or secondary enforcement.

- ***Collision avoidance systems:*** A collision avoidance system could have detected the crash attenuator and alerted the driver to the hazard. The bus involved in this crash was not equipped with such a system.

Recommendations

As a result of this investigation, the NTSB makes new safety recommendations to the Federal Highway Administration, the California Department of Transportation, the American Bus Association, the United Motorcoach Association, and Greyhound Lines, Inc. The NTSB also reiterates recommendations to the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the state of California, and Motor Coach Industries International, Inc.

1 Factual Information

1.1 Crash Narrative

On Tuesday, January 19, 2016, about 6:37 a.m., a 2014 Motor Coach Industries International, Inc. (MCI), D4505 motorcoach, operated by Greyhound Lines, Inc., was traveling northbound on US Highway 101 (US-101) in San Jose, Santa Clara County, California, when it entered and traveled in an unmarked gore area, rather than the intended high-occupancy-vehicle (HOV) lane, and collided with a crash attenuator.¹ The bus was occupied by the 58-year-old driver and 21 passengers. It had departed Los Angeles at 11:53 p.m. on January 18 and made stops in Avenal and Gilroy. The scheduled route to Oakland also included stops in San Jose and San Francisco (see figure 1). The weather conditions in the San Jose area were dark, with moderate-to-heavy rain and reported winds from the east-southeast at 20 mph, with gusts reaching 28 mph. The traffic conditions on US-101 north were moderate to heavy.



Figure 1. Map showing bus travel route and crash location.

¹ (a) Throughout the report, the motorcoach involved in this crash is referred to as the “bus.” (b) A gore area is typically a triangular-shaped boundary created by white lines and delineated by diagonal cross-hatching or chevrons. Its purpose is to separate an entrance or exit lane from the main lanes of a highway. The gore at this location was a theoretical gore—that is, a marked area of pavement formed by convergence or divergence of the edges of a main lane and an exit/entrance lane. (c) A crash attenuator is a device intended to reduce the damage to structures, vehicles, and motorists resulting from a motor vehicle collision. It is designed to absorb the colliding vehicle’s kinetic energy.

As shown in figure 2, at the US-101–State Route 85 (SR-85) interchange—where the crash occurred—US-101 north consists of:

- A single left exit HOV lane for SR-85 (yellow arrow on figure 2)
- A single US-101 HOV lane (green arrow)
- Three conventional US-101 lanes (red arrows)
- Two right exit conventional lanes for SR-85 (blue arrows).

A 990-foot-long gore with an unmarked inside area separates the left exit HOV lane for SR-85 from the US-101 HOV lane. The gore widens to about 22 feet at the point where a reusable energy-absorbing crash terminal (REACT) 350, nine-cylinder crash attenuator is in place, in advance of a 3-foot-high concrete barrier. The barrier physically separates the left exit HOV lane for SR-85 from the US-101 HOV lane.

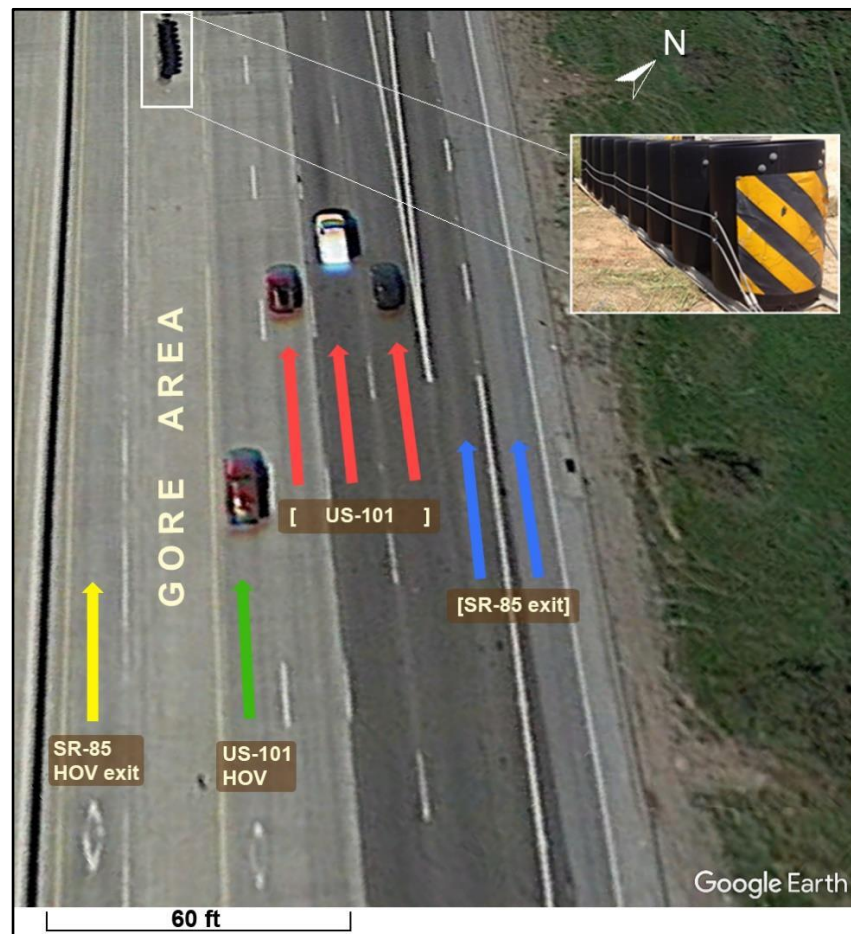


Figure 2. Depiction of travel lanes and gore area at US-101–SR-85 northbound interchange. Retroreflective object marker on lead cylinder of exemplar crash attenuator, shown in inset, was not present on January 19, 2016. (Source: Google Earth, image date March 28, 2015)

Video evidence shows that the bus was traveling in the US-101 HOV lane (green arrow in figure 2) as it approached the interchange. Then, the driver initiated a movement to the left, into the gore area. But, instead of entering the left exit HOV lane for SR-85 (yellow arrow in figure 2), as the driver reported to the California Highway Patrol (CHP) he had intended to do, he maintained the vehicle's path in the gore until colliding with the crash attenuator. The bus then rode up the concrete barrier, yawed counter-clockwise, and rolled 90 degrees to the right. As shown in figure 3, the bus came to rest on its right side against the concrete barrier, with its aft section resting on the US-101 HOV lane and its front hanging over the left exit HOV lane for SR-85.² The bus had traveled 65 feet from the point of initial impact with the crash attenuator to its final rest position.

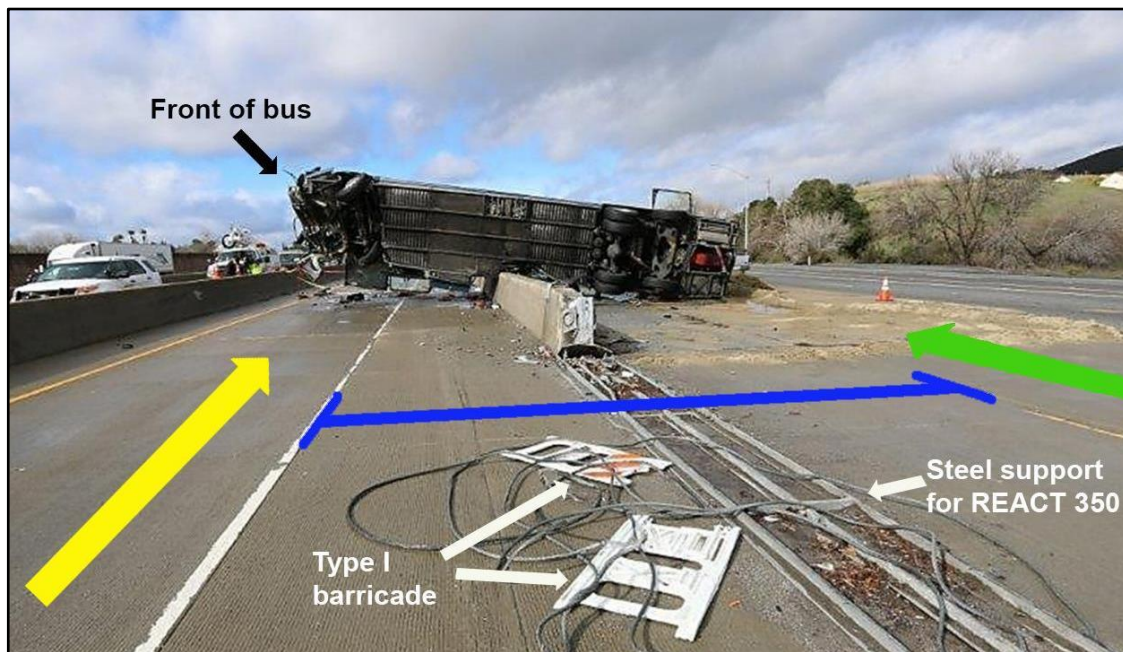


Figure 3. At-rest position of bus atop concrete barrier, straddling left exit HOV lane for SR-85 (yellow arrow) and US-101 HOV lane at right (green arrow). Depicted are: (a) steel plate in front of concrete barrier, which supported REACT 350 crash attenuator; (b) blue line marking width of gore (22 feet at this location); and (c) type I barricade, which was not visible to driver at time of crash. (Source: California Highway Patrol)

² The California Department of Transportation (Caltrans) had placed the type I temporary barrier in front of the crash attenuator on December 6, 2015, following another crash. See section 1.5.2 for more information.

1.2 Injuries

As a result of this crash, two of the 21 bus passengers died, two sustained serious injuries, 11 received minor injuries, and three were uninjured.³ The driver sustained minor injuries. Eight passengers and the driver were transported from the crash scene to area hospitals, and three passengers went to area clinics at a later time. Table 1 summarizes the injury information.

Table 1. Injury levels for bus occupants.^a

	Fatal	Serious	Minor	None	Unknown	TOTAL
Driver	--	--	1	--	--	1
Passengers	2	2	11	3	3	21
TOTAL	2	2	12	3	3	22

^a Although 49 *Code of Federal Regulations (CFR)* Part 830 pertains to the reporting of aircraft accidents and incidents to the NTSB, section 830.2 defines fatal injury as any injury that results in death within 30 days of the accident, and serious injury as any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date of injury; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.

Both passengers who died were ejected through the windshield. Their injuries included blunt force trauma to multiple body regions, fractures, and lacerations. Although the exact seating locations of the two deceased passengers could not be determined from available evidence and witness statements, they were likely seated in the first few rows of the bus because of their ejection through the windshield.

The two seriously injured passengers sustained fractures, abrasions, lacerations, and contusions. Both passengers were seated adjacent to a window on the driver side in the middle of the bus, and neither was restrained at the time of the crash.

Passengers with minor injuries generally sustained lacerations, contusions, and abrasions. The driver was wearing only the lap portion of his lap/shoulder belt, which had a detachable shoulder harness. He was partially ejected from the bus when his seat separated from the floor structure; first responders found him restrained in the driver seat with his head and upper torso hanging out of the displaced windshield. Of the 11 passengers who received minor injuries, none were restrained at the time of the crash. A passenger seated toward the center of the bus on the right side in an aisle seat reported that she was partially ejected, with her upper torso hanging outside the window. She sustained minor injuries.

Of the three passengers who were uninjured, two were restrained with lap and shoulder belts; and they were seated toward the rear of the bus on the right side. They stated that they remained in their seats postcrash and were hanging from the belts.

³ Three other passengers were not transported to area hospitals, and no medical records were obtained. National Transportation Safety Board (NTSB) investigators attempted to contact each of the three passengers but received no response.

1.3 Egress and Emergency Medical Services

Based on the 11 passenger interviews conducted by National Transportation Safety Board (NTSB) investigators, at least three passengers egressed through the rear roof hatch of the bus, while the remaining interviewed passengers egressed through the broken emergency exit windows on the right side.⁴ According to first responders, the bus driver egressed through the displaced windshield with assistance.

A CHP dispatcher was notified of the crash at 6:38 a.m., just 1 minute after its occurrence. The Rural Metro ambulance service was near the crash location at the time of the call and self-dispatched to the scene, arriving at 6:54 a.m.⁵ The San Jose Fire Department (SJFD), engine 27, arrived on scene at 6:55 a.m. At that time, the SJFD incident commander reported two deceased passengers and about 20 injured. The battalion chief arrived at 6:58 a.m. and assumed command for the duration of the emergency response. He initiated a multiple patient management plan based on early reports from the crash location.⁶

The SJFD dispatched five engine units, two trucks, and two response units. Rural Metro dispatched five ambulance units, which transported eight passengers to area hospitals.⁷

1.4 Occupant Protection

1.4.1 Seats

The passenger seats on the bus were Premier model seats produced by IMMI. The seats have a dual frame design and lap/shoulder belts. Seat belt use instructions, stitched into the seatbacks, explain the two-step restraining process.⁸ The dual frame seatback is marketed as a system that protects the belted occupant and potentially protects an unbelted occupant in the seat behind.⁹ The seatback incorporates two frames. The inner frame is designed to support the lap/shoulder belt; during loading, it allows the seatback to rotate forward, thereby absorbing energy. The outer frame is designed to remain in the original upright position.

⁴ In this context, “egress” indicates the bus occupant’s method of exiting the bus, either through a designated emergency exit—a roof hatch or a door—or by other means, such as the displaced windshield.

⁵ Rural Metro ambulance staff heard the dispatcher’s call to the San Jose Fire Department (SJFD) while monitoring the emergency channel.

⁶ The multiple patient management plan is a component of the Santa Clara County medical response system, which was designed to provide guidance to emergency response personnel through coordinated incident management. The battalion chief activated level 2 of the management plan. Level 2 applies when an incident involves more than 10 people—but less than 20—who require ambulance transport.

⁷ Seven passengers were transported to hospitals from the crash scene. One hour after the crash, another passenger was found disoriented and wandering in a nearby parking lot; he was transported to the hospital.

⁸ The instructions stated: (1) buckle the seat belt; (2) adjust the clip at the shoulder harness for a better fit.

⁹ The outer frame of the seatback remains upright during impact. This design—though not its primary function—may restrict the forward momentum of an unbelted passenger seated behind. Because this benefit could only be realized in crashes with specific dynamics—such as those with no lateral impact—wearing a seat belt provides the best protection.

USSC Group manufactured the driver seat, which had an integrated lap/shoulder belt. During the crash sequence, the seat detached from the floor structure. It was found near the front boarding door, with the seatback pressed against the door and the headrest near the windshield. Examination of the seat revealed that the floor structure onto which it was attached was displaced rearward during the crash sequence, which displaced the seat rearward toward the raised passenger floor structure. Contact between the driver seat base and the passenger floor structure caused the failure of the bolts that attached the seat to the floor. As a result of these findings, on February 28, 2017, the NTSB adopted a safety recommendation report to MCI detailing the circumstances of this crash and issuing one recommendation pertaining to the driver seat attachment (NTSB 2017).

1.4.2 Usage and Condition of Restraints

The driver seat was equipped with a lap/shoulder belt. The lap portion of the seat belt showed evidence of loading, with cupping and striations to the webbing, while the shoulder harness remained stored and locked in the retractor. Emergency responders noted that the driver was using only the lap portion of the seat belt.

Only two of the 11 interviewed passengers reported using the available passenger lap/shoulder belts. NTSB investigators examined the seat belts and found no distinct signs of loading on any of them, including those in the area of the two restrained passengers. Although some of the seat belt buckles were difficult to access, all were functional.¹⁰ NTSB investigators inspected the seat belts on an exemplar motorcoach provided by Greyhound and found that all the buckles were accessible. Although nine of the buckles were missing covers, all but one properly latched.

1.4.3 Carrier Policies and State and Federal Regulations

Greyhound has mandatory procedures for both pretrip and posttrip vehicle inspections, but those procedures do not include inspecting the condition and accessibility of passenger seat belts.

According to the CHP interview of the bus driver, he stated that he made a pretrip safety announcement prior to departure, including instructing passengers to use the seat belts. However, each of the passengers interviewed by NTSB investigators reported that the driver did not conduct a pretrip safety briefing or provide any other safety instructions.

Greyhound does not have a prerecorded safety briefing; instead, it provides drivers with a script that includes a statement instructing the passengers to wear their seat belts. However, the carrier does not require drivers to make this announcement. The Federal Motor Carrier Safety Administration (FMCSA) does not require passenger motor carrier operators to provide pretrip safety briefings; it only recommends the practice: “Fixed route motorcoach service operations

¹⁰ The seat belt buckles for the window seats on both sides of the bus were attached to the end of a rigid stalk, which was designed to protrude from the seat pans. Eight seat belt buckles in the window seats were pushed down between the seat pans of the window and aisle seats. Although NTSB investigators could pull the stalks upward, the buckles were not immediately accessible.

should present the safety information at all major stops or terminals, after any new passengers have boarded and prior to movement of the motorcoach.”¹¹

California has a primary enforcement seat belt use law requiring that a driver and passengers, regardless of seating position, be restrained.¹² This legislation applies to common motor vehicles such as passenger vehicles, motorized trucks, truck-tractors, and farm labor vehicles, but it does not include motorcoaches.¹³ Additionally, FMCSA regulations require that the driver of a commercial motor vehicle be restrained, but this requirement does not extend to the passengers of commercial vehicles.¹⁴

1.5 Highway Factors

1.5.1 Description and General Characteristics

This crash occurred in the gore area of the US-101–SR-85 interchange, near milepost 26, within the city limits of San Jose. As shown in figure 2, the northbound roadway at this location consists of the following:

- Single left exit HOV lane for SR-85.
- Gore with an unmarked inside area, which separates the left exit HOV lane for SR-85 from the US-101 HOV lane.
- Single US-101 HOV lane.
- Three conventional US-101 lanes.
- Two right exit conventional lanes for SR-85.

Safety lighting in the area of the crash includes seven light poles at 180-foot intervals along the right side of the roadway, including one pole adjacent to the crash site.

¹¹ See the [FMCSA website](#), accessed November 1, 2016.

¹² (a) Primary enforcement seat belt use laws allow enforcement officers to ticket a driver/vehicle occupant for not wearing a seat belt without the driver having committed any other traffic offense. Typically, drivers are cited for themselves and other passengers under a certain age; the maximum age varies across states. Adult occupants not wearing a seat belt are themselves cited. (b) Secondary enforcement seat belt use laws allow enforcement officers to ticket a driver/vehicle occupant for not wearing a seat belt only after stopping the vehicle for another offense.

¹³ The California Vehicle Code, section 27315, specifies details of the seat belt use legislation, referred to as the “Motor Vehicle Safety Act.”

¹⁴ At the time of the crash, 49 *CFR* 392.16 stated the following regarding a commercial vehicle driver’s seat belt use: “A commercial motor vehicle which has a seat belt assembly installed at the driver’s seat shall not be driven unless the driver has properly restrained himself/herself with the seat belt assembly.” This regulation has since been amended (49 *CFR* 392(a), effective August 8, 2016) to state: (a) *Drivers*. No driver shall operate a commercial motor vehicle, and a motor carrier shall not require or permit a driver to operate a commercial motor vehicle, that has a seat belt assembly installed at the driver’s seat unless the driver is properly restrained by the seat belt assembly.”

Each of the northbound lanes at the crash location is 12 feet wide. The roadway has an 8-foot-wide right shoulder and a 5-foot-wide median shoulder, which are delineated from the travel lanes by solid white and yellow lines, respectively. Yellow reflectors at 48-foot intervals further delineate the median shoulder.

The speed limit on US-101 in the vicinity of the crash is 65 mph. The 2014 average annual daily traffic for this segment of US-101 was 142,000 vehicles, 8.5 percent of which were heavy vehicles. According to the California Department of Transportation (Caltrans), the average speed of traffic at the time and location of the crash was 56.6 mph.¹⁵

1.5.1.1 Gore Area. The apex of the gore area that separates the left exit HOV lane for SR-85 from the US-101 HOV lane begins about 990 feet from the crash attenuator. At the location of the attenuator, the gore is 22 feet wide. The inside area of the gore is unmarked.

1.5.1.2 Crash Attenuator. A REACT 350 crash attenuator is in place in advance of the 3-foot-high concrete barrier at the end of the gore. The crash attenuator is composed of nine 36-inch-diameter cylinders, which are secured by steel cables and placed on a steel plate anchored into the concrete (see figure 4). By design, the walls of the cylinders increase in thickness from front to rear to absorb impact energy in a controlled manner. The device is classified as a re-directive attenuator that meets test level (TL)-3 criteria (Transportation Research Board [TRB] 1993).¹⁶

The lead cylinder of the crash attenuator is designed to include a retroreflective object marker. According to the manufacturer, this marker meets or exceeds the standards of ASTM International (ASTM) for type III and IV reflective sheeting.¹⁷ Although the object marker is standard on the REACT 350, it was not present on the lead cylinder at the crash location, as discussed below.

¹⁵ According to the Caltrans vehicle-detecting system real-time traffic-monitoring station on US-101, 2 miles south of the crash location, for January 19, 2016, the average vehicle speed from midnight until 5:00 a.m. was 70 mph, at which point traffic started slowing down. By 6:45 a.m., the average speed was 56.6 mph. Caltrans noted that this speed corresponds to the average speed reduction during normal commuting hours and was reasonable for the driving conditions. For additional information, see the NTSB public docket for this investigation.

¹⁶ Based on the National Cooperative Highway Research Program (NCHRP) Report 350, TL-3 allows a barrier to be impacted by a pickup truck with a gross vehicle weight rating (GVWR) of 4,400 pounds, traveling at 62 mph at a 20 degree angle or at 60 mph at a 0 degree angle, without exceeding vehicle occupant injury parameters. According to the manufacturer, the REACT 350 meets TL-3 criteria.

¹⁷ According to ASTM standard D4956, type III and IV sheeting must meet the minimum coefficient of reflectivity measured in candelas per lux meter squared at a 0.2 degree observation angle and a minus 4 degree entrance angle.



Figure 4. Front and side view of REACT 350 attenuator located 1 mile from crash site on US-101 south.

1.5.1.3 Crash History. At NTSB request, Caltrans provided the crash history for a 2-mile segment of US-101. In the previous 8 years, eight crashes occurred at this location, five of which involved a vehicle striking the subject attenuator.¹⁸ The most recent such incident occurred on December 6, 2015—about 6 weeks before this crash—and resulted in displacement of, and damage to, the retroreflective object marker.

1.5.2 Maintenance of Traffic Safety Devices

In response to the December 6, 2015, crash, Caltrans issued a work order within its integrated maintenance management system (IMMS), a work order database. Caltrans requires clearing a crash scene and, if necessary, placing temporary delineation barricades within 24 hours. Department policy also requires that crash attenuators be repaired within 7 days.

1.5.2.1 Crash Attenuators. Notes in the IMMS work order regarding the December 6, 2015, crash indicated that by the end of that day, the repair crew had re-set the cylinders on the REACT 350 track system and repaired the hardware. The work order did not mention that the work was incomplete or that an object marker was needed to complete the repair.¹⁹ The Caltrans maintenance crew supervisor stated that a replacement object marker was located on December 11, but it was not installed due to training and holiday schedules.

¹⁸ Caltrans issued five work orders for repair of this crash attenuator, though only four crashes had been reported. For the other repair request, it is presumed that the vehicles left the scene.

¹⁹ IMMS work orders have a “work date” box to indicate the date of the (initial) repair, but they do not have a separate checkbox to indicate whether a repair has been completed.

In addition to having a work order within IMMS, Caltrans requires proprietary devices such as the REACT 350 to have a separate repair checklist. Energy Absorption Systems, the manufacturer of the REACT 350, provides both detailed repair instructions and the checklist, which contains a separate section for selection of the retroreflective object marker. The Caltrans requirement states that “Each individual device must have the manufacturer’s checklist signed off by the crew supervisor, and superintendent or district safety devices coordinator after each repair.”

Caltrans policy states that IMMS work orders for proprietary devices should not be closed until the district safety devices coordinator has either inspected the repair or received a copy of the repair checklist; the coordinator is required to retain the copy. In this case, the proprietary device checklist for repair of the crash attenuator following the December 6, 2015, crash was never initiated; and the attenuator was missing its retroreflective sheeting for 44 days before the subject crash on January 19, 2016.

1.5.2.2 Temporary Barricades. Notes from the IMMS work order for the December 6, 2015, crash indicated that the Caltrans repair crew also placed two type I barricades in front of the REACT 350 (see figure 5). Type I barricades are used to close, restrict, or delineate road use.

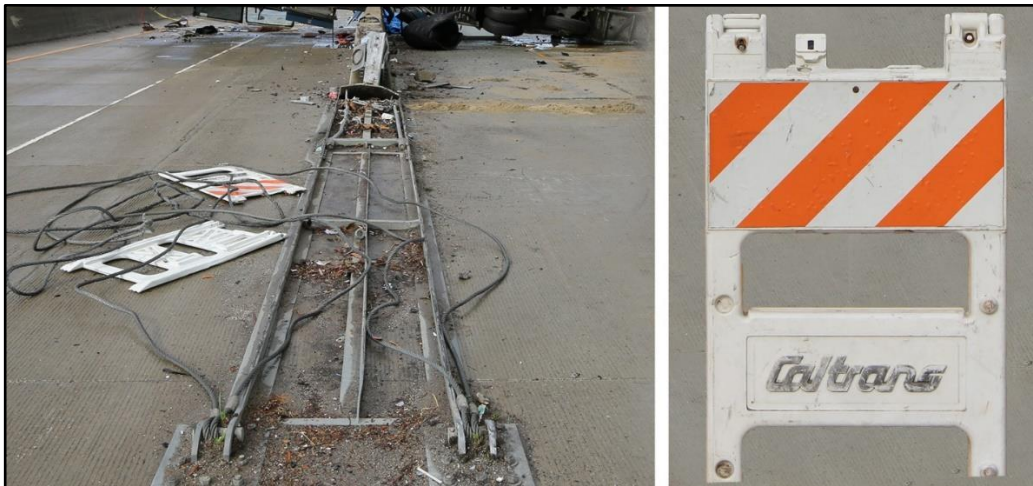


Figure 5. Displaced type I barricade in front of crash attenuator and next to steel support plate (left), and example of Caltrans type I barricade (right).

Based on evidence from the forward-facing DriveCam camera on the bus (see section 1.6.5), at the time of the crash, in the early morning of January 19, 2016, the type I temporary barricades did not delineate the crash attenuator. They were not visible to the driver.²⁰ After the crash, one barricade was located to the side of the steel support for the crash attenuator (see figure 5); and the other was found in the US-101 HOV lane, about 20 feet west–northwest of the final rest position of the bus. Caltrans has no policy for inspecting temporary barricades.

²⁰ Upon close inspection of frames of the recording from the forward-facing camera, NTSB investigators determined that one of the type I barricades was lying flat, behind and to the side of the crash attenuator.

Type I barricades weigh 14 pounds without ballast and a maximum 24 pounds with ballast. According to the Caltrans maintenance supervisor, the type I barricades at the crash location were ballasted with sand, which was poured into the legs. NTSB investigators weighed two exemplar type I barricades used by Caltrans, and they weighed 19–20 pounds.²¹ Tests conducted to determine the wind force required to displace the exemplar barricades showed that, depending on the direction of the wind, they could withstand wind speeds of 18–21 mph before falling.

1.5.3 Left Exit Lane and Gore Delineation

The left exit HOV lane for SR-85 formed about 3,825 feet from the crash attenuator. The exit lane, the gore, and the US-101 HOV lane were delineated as follows:

- The left exit HOV lane was delineated from the US-101 HOV lane by a broken white line up to 1,280 feet from the crash attenuator, at which point it changed to a solid white line.
- The gore was delineated from the left exit HOV lane by a solid white line—and from the US-101 HOV lane by a solid white line up to about 309 feet from the attenuator, at which point it changed to a solid yellow line.

Section 3A.06 of the California *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) describes a solid line as prohibiting or discouraging crossing, depending on the specific application.

The solid line delineating the gore from the left exit HOV lane for SR-85 and the US-101 HOV lane is 8 inches wide, and the broken lines delineating the travel lanes are 4 inches wide. However, the lane markings delineating the gore area from the left exit HOV lane for SR-85 were worn at the time of the crash. As shown in figure 6, the left edge line of the gore was completely worn off in the initial third of the gore and sporadic through the remainder. Since the crash, Caltrans has repainted the lanes at the crash location.

²¹ The type I barricades at the crash scene sustained too much damage to be reliably weighed.

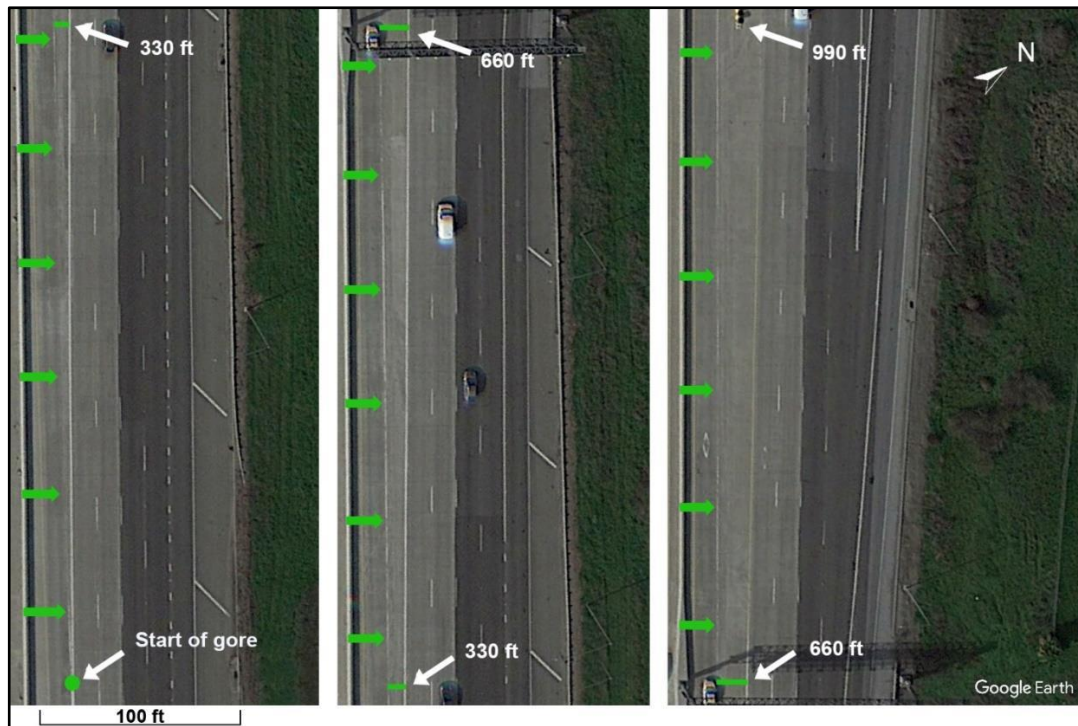


Figure 6. Depiction of gore lane lines, marked with green arrows: left edge line completely absent in initial third of gore (left image), and left edge line sporadic in middle (center image) and final third of gore (right image), with white arrows and measurements indicating distance from crash attenuator. (Source: Google Earth, depicting crash location on January 26, 2016)

Figure 6 also shows that the inside of the gore is not marked with optional diagonal cross-hatching or chevrons. According to section 3B.24 of the MUTCD, such markings may be used to discourage travel on certain paved areas, such as gores. As of March 2017, Caltrans had not delineated the inside of this gore. The state does not require marking gores with diagonal cross-hatching or chevrons.

1.5.4 Guide Signage

The HOV overhead signs in advance of the US-101–SR-85 interchange were installed from 2005 to 2008. Signs for the left exit HOV lane were placed as follows:

- 1 mile in advance of the crash attenuator (before formation of the left exit HOV lane)
- 0.5 mile in advance of the attenuator (see figure 7)
- About 328 feet in advance of the attenuator.

The signs complied with the MUTCD at the time of installation. As a result of an NTSB investigation of a 2007 motorcoach crash in Atlanta, Georgia—which occurred at a left exit HOV lane—the Federal Highway Administration (FHWA) codified new standards into the revised MUTCD, including those pertaining to HOV and left exit signage (NTSB 2008; FHWA 2009). The final revision included requirements for (1) left exit signs to have an additional

plaque at the top left corner, and (2) preferential lane or exit signs to have a header across the top.²² The compliance date for these requirements was December 31, 2014, though signs without the full border on top indicating a preferential lane could remain in place until the end of their useful life. New signs must meet both requirements.



Figure 7. Noncompliant guide sign for left exit HOV lane for SR-85, located 0.5 mile in advance of crash attenuator (left); and example of compliant sign with left exit plaque (right).

The guide signs on approach to the crash location were out of compliance with the MUTCD requirement for left exit plaques (see figure 7). However, because these signs were placed before the FHWA ruling, they were not out of compliance with the requirement for a full border on top indicating a preferential lane. New signs without the full border indicating a preferential lane would be out of compliance for that MUTCD requirement.

At the request of NTSB investigators, the FHWA issued an official ruling confirming that the left exit tab plaques should have been installed on the left exit sign at the crash location by December 31, 2014.²³

Additionally, the last two signs for the left exit HOV lane for SR-85—located 0.5 mile and 328 feet in advance of the crash attenuator—were located on overhead structures that each had five guide signs. The MUTCD, section 2E.11, indicates that an overhead structure should display no more than three guide signs.

1.6 Vehicle Factors

1.6.1 General

The accident bus was a 50-passenger 2014 MCI D4505, equipped with a Cummins ISX12 engine and an Allison B500 automatic transmission. The bus had a gross vehicle weight rating (GVWR) of 50,000 pounds and was electronically limited to a maximum speed of 68 mph.

²² See 74 *Federal Register (FR)* 66730, December 16, 2009.

²³ See the highway factors report in the NTSB public docket for this investigation, FHWA letter to NTSB, “Official Ruling 1(09)-5(I), Applicability of Compliance Date to Preferential Lane Signing,” April 8, 2016.

1.6.2 Damage

1.6.2.1 Exterior. As a result of the crash, the bus sustained contact damage to the front end, the undercarriage, and the right side, and induced damage to nearly all other areas. The initial impact with the crash attenuator and concrete barrier damaged the entire front end of the bus (see figure 8). The damage transitioned from the front to the undercarriage and into the right front wheel assembly, as noted below:

- Metal floor bracing was buckled vertically about 12.5 inches at the second row of seats.
- Front right wheel assembly was deformed rearward into the back of the wheel well.
- Entrance stairwell was crushed and shifted rearward 30 inches.
- Boarding door was partially attached and hanging from the door frame, with the bottom half of the door bent upward almost 180 degrees.

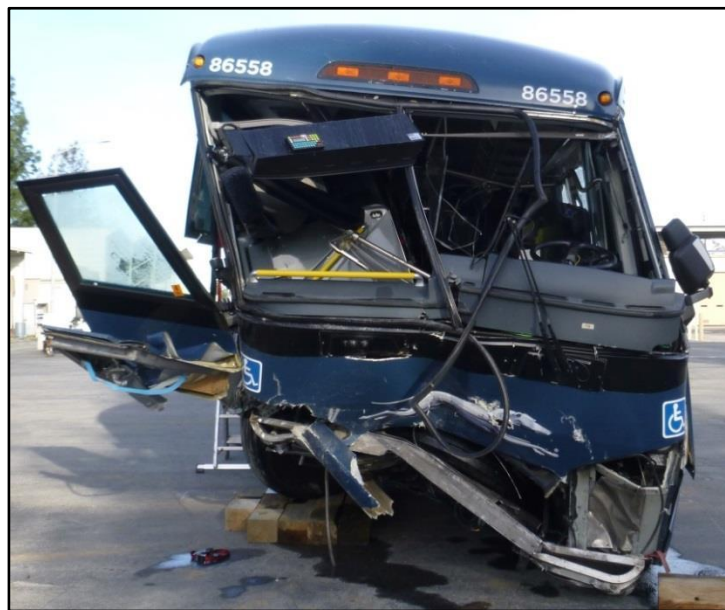


Figure 8. Bus postcrash, showing extensive frontal damage.

The second impact (quarter roll to the right), onto the concrete barrier, resulted in damage that extended from the base of the bus up to the roof rail on the right side, near the battery and electrical compartment. This compartment sustained extensive upward displacement and induced damage, which crushed the two batteries and the master power shutoff switch.

The third axle was displaced evenly rearward, wedging the rear tires into the wheel well and damaging the rear body panels. At the rear of the bus, the engine was displaced rearward and upward, and the transmission housing was broken and displaced upward. During the collision

sequence, the fire suppression system triggered a release of dry chemical extinguisher into the engine compartment.²⁴

1.6.2.2 Windows. The bus was equipped with eight double-paned windows on each side. The exterior window layer was tinted and tempered, and the interior layer was laminated. All eight windows on the left side and six windows on the right side were emergency exit windows.²⁵

The crash displaced both windshield panes of the bus and three windows on the left side. One window on the left side remained in the frame but sustained damage. Four windows on the right side were partially displaced, while one remained in the frame but sustained damage.

1.6.3 Inspection

1.6.3.1 Mechanical Systems. Damage to the bus affected all major mechanical systems. NTSB investigators performed functional checks of braking, suspension, and electrical systems, as well as wheels and tires. The examination revealed no evidence of preexisting vehicle damage or defects.

1.6.3.2 Inspection, Maintenance, and Safety Recalls. The bus passed its most recent annual inspection on December 18, 2015. Vehicle records document a variety of regularly scheduled preventive maintenance and repairs. One safety recall had been issued for the bus—under certain conditions headlights may deactivate—but it was not completed. NTSB investigators examined the low beam headlight filaments and determined that they were energized during the collision.

1.6.4 Data Recording Systems

1.6.4.1 Engine Control Module. The engine control module (ECM) controls engine timing and fuel injection based on various engine and sensor inputs. The ECM is also capable of providing diagnostic information associated with engine or sensor faults, as well as recording vehicle and engine speed when triggered by sudden deceleration events.²⁶

The collision sequence damaged the two batteries used to power the vehicle's electrical system. To facilitate successful data download, an external source of power was supplied to the engine. Data extracted from the ECM included a fault report and a sudden deceleration record that contained three triggered events, none of which were associated with the timing of the crash. The fault report included one code at the time of the crash that was consistent with the damage to the battery compartment.

1.6.4.2 iComera Moovbox. The iComera Moovbox provides wireless Internet access to bus passengers. The device had a built-in global positioning system (GPS) receiver and was capable of transmitting GPS information to Greyhound, but it had no internal memory.

²⁴ The bus was equipped with an AMEREX fire-suppression system that continuously monitors the engine compartment for fires and releases chemical extinguisher as necessary. However, there was no evidence that the crash initiated a fire.

²⁵ Two windows on the right side were nonemergency windows because of a wheelchair access point at those locations.

²⁶ The threshold for triggering a sudden deceleration event is a 7-mph deceleration in 1 second.

Greyhound provided NTSB investigators with the data file containing GPS information from several previous trips, as well as the crash trip. The data were recorded at 0.2 Hz once every 5 seconds. Based on the last data point—at 6:35:35 a.m.—the bus was traveling 47 mph 2 minutes before the crash.²⁷ The manufacturer noted that the device sustained a power interruption after the last recorded data point.

1.6.4.3 Lytx DriveCam. The Lytx DriveCam is a monitoring and recording device that continually tracks driving performance metrics and records relevant information when triggered by critical events, such as hard braking or stability control.²⁸ The DriveCam device on this bus was mounted in the top left corner of the right windshield pane. As a self-contained unit, it consisted of:

- An onboard image recorder that contained two channels of recorded video, from both forward- and inward-facing cameras, as well as an internal microphone.
- A three-axis accelerometer that detected critical events and triggered the recording of acceleration data and the cameras.
- A GPS receiver that allowed the carrier to combine the critical event information with specific geographic coordinates.

When the system detected a critical event, it was designed to record 20 seconds of data, including video—10 seconds prior to and 10 seconds following the event.²⁹

During the crash sequence, the windshield, along with the DriveCam system, separated from the bus. First responders located these components. Data from the device were downloaded at the manufacturer's facility.

The extracted data showed that the DriveCam system captured crash-relevant information, including 20 seconds of acceleration data, 20 seconds of video data from both the forward- and inward-facing cameras, and 11 seconds of GPS information.³⁰

Based on the video from the forward-facing camera and deceleration data, the impact with the crash attenuator occurred about 6:37:35 a.m. According to GPS data, the bus was traveling 56 mph 1 second before impact. Data from the accelerometer showed a sudden deceleration of 13 mph 1 second after impact, but no evidence of pre-impact braking by the driver. Table 2 shows the speeds at which the bus was traveling in the last 2 minutes before the collision.

²⁷ Because of the sudden loss of power, data transmission to the cloud network was incomplete, resulting in the lack of GPS information for almost 2 minutes before impact.

²⁸ The threshold for triggering a hard braking event is a 9-mph deceleration in 1 second—and for a stability control event, lateral movement of at least 0.4 g.

²⁹ The cameras recorded video at four frames per second; the acceleration information was recorded at 20 Hz, and the GPS recorded information at 1 Hz.

³⁰ The delay in acquisition of the GPS signal and the transmission of data are the likely reasons for reduced data from the GPS receiver.

Table 2. Selected parameters recorded by, and derived from, iComera and DriveCam systems.

Time (a.m.)	Speed (mph)	Device
6:35:35	47	iComera GPS
↕	average = 59	<i>Derived</i> ^a
6:37:27	61	DriveCam GPS
6:37:28–6:37:34	range: 60–57	DriveCam GPS
6:37:35	56	DriveCam GPS

^a The last data point from the iComera and the first data point from the DriveCam were used to calculate the speed at which the bus would have to have been traveling to cross the distance between those two points.

1.6.5 Examination of Camera Recordings

The video recordings from both the forward- and inward-facing DriveCam cameras were examined. NTSB investigators and party representatives derived the following descriptions after detailed, frame-by-frame viewing of the recordings.³¹ The recordings from both cameras started at 6:37:25 a.m.—about 10 seconds before the crash.

1.6.5.1 Forward-Facing Camera. Because of the positioning of the DriveCam system on the windshield, the forward-facing camera was outside the range of the windshield wipers. Throughout the pre-impact segment of the video, rain droplets are prominent across the entire forward field of view, and other vehicles are moving at the speed of, or faster than, the bus.³² At the start of the recording, the bus is traveling in the US-101 HOV lane, and a solid white line is visible to the left of the bus, along with pavement reflectors. Eight seconds before the crash, about 739 feet from the crash attenuator—the bus begins to move to the left, into the gore area. Three seconds later, about 493 feet from the attenuator, the bus is entirely within the gore, as shown in the middle panel of figure 9.

³¹ See the onboard image recorders report in the NTSB public docket for this investigation for a complete description of the recordings from the DriveCam cameras. NTSB investigators and representatives from the FHWA, Greyhound, and Trinity Industries—the parent company of the REACT 350 manufacturer—examined the video recordings.

³² Because of the predawn conditions, as well as the resolution and positioning of the DriveCam forward-facing camera, it is unlikely that the recording depicted exactly what the driver saw.

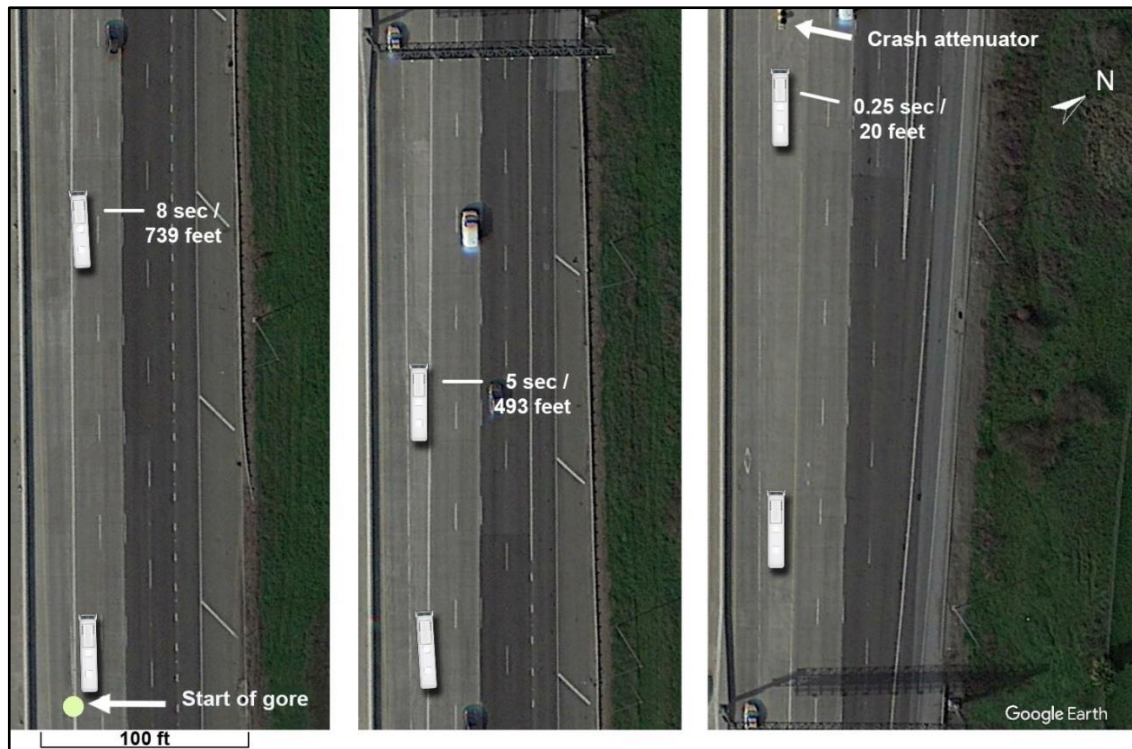


Figure 9. Depiction of movement of bus into gore and proceeding to point of impact, showing in each panel time to impact and distance to attenuator. (Source: Google Earth, depicting crash location on January 26, 2016)

The video does not show any objects directly ahead of the bus until 4 seconds before the crash, at which point a small reflective object was noticeable. The object was distinguishable 3 seconds later, 1 second before the crash. It was identified as a small exit sign mounted on the concrete barrier, behind the crash attenuator.³³ Also at this time, because of a vertical reflection of light from the headlights, a black object beneath the sign became noticeable.³⁴ In addition, a white object was seen lying flat on the ground behind and to the left of the black object.³⁵

NTSB investigators could not positively identify the black object as a crash attenuator even 0.2 second before impact. The recording showed the bus striking the crash attenuator with no perceptible change in heading. The forward-facing camera recorded about 10 seconds of postcrash video, but the roadway was not captured because of displacement of the windshield.

1.6.5.2 Inward-Facing Camera. The inward-facing camera was pointed straight down the aisle of the bus and captured the driver's head and the front row of passenger seats. Rows rearward of the first row are not discernible because of the height of the passenger seatbacks, as well as the

³³ The sign is mounted on a 4-foot-high post, affixed to the 3-foot-high concrete barrier. It is located behind the last cylinder of the crash attenuator.

³⁴ By the end of the video, NTSB investigators determined that the black object had to have been the lead cylinder of the crash attenuator.

³⁵ This object was likely one of the type I barricades. Its location is consistent with the location of one barricade found postcrash (see figure 5) and with it being displaced and having fallen over prior to the crash.

resolution of the camera. Additionally, a visor blocks the view of the driver's torso and legs. The recording shows that the driver is wearing glasses and generally facing forward. On two occasions, he slightly rotates his head to the left in a manner consistent with observing traffic; and in the last 4 seconds before impact, he is facing forward. The driver does not show any indication that he has detected the imminent hazard, even in the last frame before impact. The inward-facing camera recorded about 10 seconds postcrash, but again, due to the windshield separation, the video system did not record any relevant postimpact interior, roadway, or vehicle information.

1.7 Bus Driver

1.7.1 General

The bus driver was a 58-year-old male who had been working as a driver for Greyhound since April 1988. At the time of the crash, he held a current California class "B" commercial driver's license (CDL) with a passenger endorsement and a restriction that required him to wear corrective lenses when driving.

A CDL information systems inquiry revealed one speeding violation in 2015.³⁶ The driver's motor vehicle records show that he had an additional traffic infraction in 2011 but no reportable accidents or other traffic-related offenses.³⁷

Greyhound records show that the driver had a break in service between June 24 and October 24, 2015, because of a foot injury. He obtained a "return to work" medical release from his family physician on October 22, 2015.

The driver was issued a CDL medical certificate on October 22, 2015, which was restricted to 1 year because of his history of high blood pressure and type II diabetes. Both conditions were being treated with oral medication.³⁸ The medical certification examination did not identify diabetic peripheral neuropathy, which had been documented by the driver's personal physician 1 week before the crash and was first diagnosed in September 2015.³⁹ Additionally, the certification examination did not document whether the driver had diabetes-induced vision-impairing retinal disease. Because the driver refused an interview, NTSB investigators were unable to conclusively determine whether he had diabetes-induced visual impairment, or the extent of the decreased sensation in his feet and ankles. According to the certification

³⁶ The Commercial Driver's License Information System (CDLIS) is a nationwide computer system that enables state driver licensing agencies to ensure that each commercial driver has only one driver's license and one complete driver record. State driver licensing agencies use CDLIS to transmit out-of-state convictions and withdrawals, to transfer the driver record when a CDL holder moves to another state, and to respond to requests for driver status and history.

³⁷ This infraction was due to his failure to stop at the limit line before a stop sign or red light.

³⁸ These prescription medications were neither intoxicating nor incapacitating. For more information, see the medical report in the NTSB public docket for this investigation.

³⁹ Diabetic peripheral neuropathy is a condition of decreased sensation in the extremities resulting from nerve damage due to poorly controlled diabetes.

examination, the driver was 5 feet 7 inches tall and weighed 150 pounds, with a corresponding body mass index of 23.5. His corrected vision was 20/20.

1.7.2 Drug Testing

1.7.2.1 History. On December 2, 2010, the bus driver did not immediately report for random federally mandated drug testing.⁴⁰ He was subsequently terminated for violating a zero-tolerance drug policy. The driver filed a grievance with the Amalgamated Transit Union, which represents Greyhound drivers, and was reinstated. As a condition of reinstatement, he was required to undergo the return-to-duty process, which included completing a 2-week treatment program and submitting to multiple unannounced followup alcohol and drug tests for 2 years. Greyhound records indicate that the driver submitted to 19 alcohol tests and 19 drug tests in the ensuing 24 months, all of which were negative. The driver's most recent precrash return-to-duty drug test occurred in October 2015 and was also negative.

1.7.2.2 Postcrash Testing. Multiple alcohol and drug tests were performed on the driver's blood and urine samples after the crash. The hospital that admitted the driver obtained a blood sample from him at 7:42 a.m.—about 1 hour postcrash—and tested it for alcohol; the results were negative. The hospital also collected the driver's urine sample, at 9:20 a.m., and tested it for drugs; the results were negative.⁴¹ At the request of CHP, the Santa Clara County Crime Laboratory performed postcrash toxicology testing of the driver's blood sample; it was negative for alcohol and five common classes of abuse drugs.⁴² To meet the US Department of Transportation (DOT) requirement for postcrash toxicology testing, the driver's urine sample—which was collected at 1:52 p.m. that day—was analyzed for the five common classes of abuse drugs. The results were negative.

At the request of the NTSB, the Federal Aviation Administration Bioaeronautical Sciences Research Laboratory at the Civil Aerospace Medical Institute performed additional testing of the driver's blood sample. This analysis for alcohol and other drugs was also negative.⁴³

1.7.3 Activities Prior to and During Crash

NTSB investigators used information obtained from CHP, Greyhound, cellular phone records, various on-board recorders, and witness interviews to reconstruct the driver's activities prior to and during the crash. Figure 10 depicts his activities on the day of the crash and for the 4 days prior to the crash.

⁴⁰ Later that same day, the driver submitted to a test, which was negative for drugs and alcohol.

⁴¹ The hospital laboratory tested the urine sample for benzodiazepine, cocaine, opiates, phencyclidine (PCP), and delta-9-tetrahydrocannabinol (THC), the main active ingredient of marijuana.

⁴² The Santa Clara County Crime Laboratory tested the driver's blood sample for alcohol, cocaine, methamphetamine, opiates, PCP, and THC.

⁴³ Analyses conducted by the laboratory detect amphetamines, opiates, marijuana, cocaine, PCP, benzodiazepines, barbiturates, antidepressants, antihistamines, and commonly used prescription drugs. For a comprehensive list of drugs, see the [Federal Aviation Administration website](#), accessed December 6, 2016.

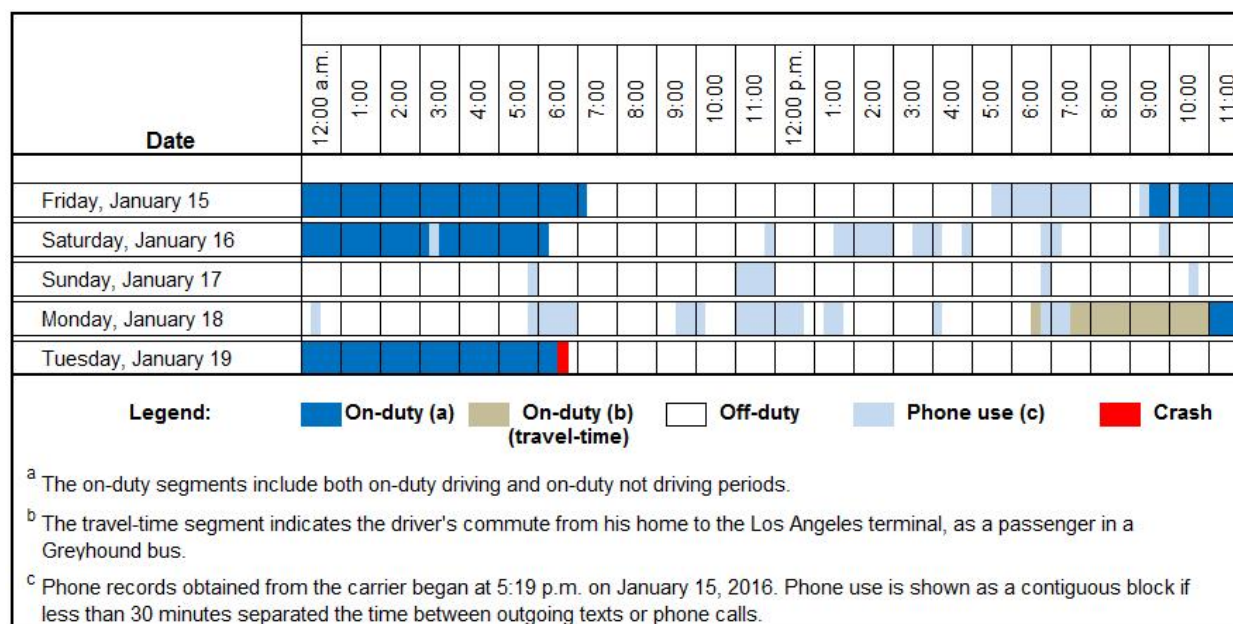


Figure 10. Precrash activities of bus driver, January 15–19, 2016.

1.7.3.1 72 Hours Prior to Crash. Based on the obtained information, the bus driver was off duty for 2 days prior to the crash. During this period, he used his cell phone intermittently in the daytime and less at night. A review of the driver's phone records indicated that his last outgoing activity on January 18 was at 7:15 p.m. That evening, the driver commuted by Greyhound—as he typically did—from his home in Victorville, California, to his home terminal in Los Angeles, a 4-hour trip. He arrived at the terminal at 10:40 p.m., about 20 minutes before the start of his shift and 50 minutes before scheduled departure.

In the 24 hours preceding the crash trip, there were several periods without cell phone use—including about 5 hours overnight on January 17–18 and a few 2–3 hour blocks in the morning and afternoon of January 18. However, it is not known to what extent the driver used those periods to sleep.

Greyhound requires that full-time drivers commute to work and finish their shifts within 15 hours, in accordance with the FMCSA hours-of-service (HOS) requirement for passenger-carrying commercial vehicle drivers.⁴⁴ Even with the bus driver's 4-hour commute to the Los Angeles terminal, he would have met these requirements had he completed his route on January 19.⁴⁵

1.7.3.2 Crash Trip. CHP investigators interviewed the driver 3.5 hours postcrash. He stated that he had driven the crash route on previous occasions and had taken the left exit HOV lane for

⁴⁴ Title 49 *CFR* 395.5 limits commercial drivers of passenger-carrying vehicles to 15 on-duty hours, which includes travel time (commute) to the departure location.

⁴⁵ On the day of the crash, the driver was scheduled to end the trip in Oakland at 7:30 a.m., after which he would rest in a hotel near the bus terminal. He was scheduled to start operating the return route from Oakland to Los Angeles at 9:30 p.m. that day, affording him 14 hours of rest.

SR-85, but it had been at least a year since he had done so.⁴⁶ He further stated that, most recently—on January 14—he had used the right exit lane for SR-85; but, on this trip, he intended to take the left exit lane. Additionally, he asked investigators whether the left exit had one or two lanes, and reported thinking in the moment before the crash that “someone had placed barrels on the road.”

1.8 Motor Carrier Operations

This section describes general information on the operations of the carrier—such as driver training, and federal and state compliance—and specific information determined to be crash-relevant, such as Greyhound’s route selection process and oversight of drivers.

Greyhound Lines, Inc., is a for-hire passenger motor carrier that operates fixed routes and charter service throughout the United States, as well as in Canada and Mexico. Greyhound is a subsidiary of the Scottish transportation company First Group.

At the time of the crash, Greyhound had 82 terminals in the United States, operated 1,178 buses across 792 fixed routes, and employed 2,163 drivers. The Los Angeles terminal, the home terminal of the driver, employed 133 drivers and housed 165 motorcoaches.

1.8.1 Carrier Training Program

According to Greyhound, only those applicants who meet the minimum qualifications—including no more than two moving violations or crashes in the previous 2 years, or three in the previous 5 years—are permitted to enter its training program. The program includes 10 hours of online training, 2 weeks at the Greyhound driving school, and 4 weeks of on-the-route training with a senior driver.

Greyhound provides refresher/remedial training for drivers who have been on leave for more than 30 days or have unsatisfactory performance. The carrier also provides annual fatigue management training, in addition to several other training modules as part of continuing driver education. One training module—on adverse weather—states that when driving in rain, a driver should, among other actions, reduce the speed of the bus by 25 percent. The bus driver had completed this module on October 28, 2015. According to Greyhound records, he was current on all required training.

⁴⁶ According to Greyhound, the driver began operating this route on January 14, 2016. Prior to that date, he had operated a northbound route from Los Angeles to San Francisco, but it did not include a stop in San Jose. See section 1.8.3 for additional information on the route selection process.

1.8.2 CHP and FMCSA Compliance

The California Vehicle Code requires CHP to inspect a motor carrier's maintenance facilities and terminals.⁴⁷ The most recent CHP inspection of the Los Angeles Greyhound terminal was on August 20, 2015, and resulted in a "satisfactory" rating.

The FMCSA has conducted 19 compliance reviews (CR) of Greyhound since October 1989. The most recent CR occurred in September 2014 and resulted in a "satisfactory" safety rating. The Motor Carrier Management Information System (MCMIS) reports that Greyhound had no behavior analysis and safety improvement categories (BASIC) in alert status at the time of the crash.⁴⁸ On two occasions in the year prior to the crash, Greyhound had exceeded the crash indicator and the driver fitness percentile thresholds.

According to the MCMIS profile, Greyhound had received 1,480 driver inspections and 906 vehicle inspections from January 20, 2015, to January 19, 2016. The driver out-of-service (OOS) rate was 0.8 percent, and the vehicle OOS rate was 3.8 percent—which are below the national OOS rates of 4.7 percent for driver and 7.1 percent for vehicle for passenger-carrying carriers.⁴⁹ In 2015, the carrier had 59 recordable crashes, two of which resulted in fatalities, 26 in injuries, and 31 in vehicles being towed. The driver involved in this crash had two roadside inspections, on February 7 and March 1, 2015, in which he received one citation for speeding 1–5 mph above the speed limit—but no OOS violations. Because of this crash, the FMCSA initiated a "focused" crash investigation and found no violations.⁵⁰

1.8.3 Route Selection

For about 2 years, until January 12, 2016, the bus driver had been operating different routes between Los Angeles and San Francisco, none of which included the northbound US-101–SR-85 interchange where this crash occurred. On January 14, 2016, the driver began operating a new route northbound from Los Angeles to San Francisco via San Jose (route number 6876). The trip on January 18–19 was the second time that he had operated this route.

⁴⁷ The California Vehicle Code, section 34501.12(a), regulates the inspection of motor carriers.

⁴⁸ (a) The FMCSA uses data from roadside inspections—including all safety-based violations, state-reported crashes, and the Federal Motor Carrier Census—to quantify a carrier's performance in seven BASICs. These categories are (1) unsafe driving, (2) HOS compliance, (3) driver fitness, (4) controlled substances and alcohol, (5) vehicle maintenance, (6) hazardous materials compliance (if applicable), and (7) crash indicator. A carrier's rating for each BASIC depends on its number of adverse safety events, the severity of its violations or crashes, and when the adverse safety events occurred (more recent events are weighted more heavily). (b) On January 19, 2016, the carrier's BASIC scores were as follows: unsafe driving, 36 percent; HOS compliance, 47 percent; driver fitness, 56 percent; controlled substances and alcohol, 0 percent; vehicle maintenance, 14 percent; and crash indicator, 48 percent—each of which is within acceptable limits as set by the FMCSA. The thresholds for passenger carriers are 50 percent for unsafe driving, HOS compliance, and crash indicator; 65 percent for driver fitness, controlled substances and alcohol, and vehicle maintenance; and 80 percent for hazardous materials.

⁴⁹ The Commercial Vehicle Safety Alliance establishes OOS criteria (CVSA 2015). A finding of an OOS condition by a qualified inspector precludes further operation by the driver or of the vehicle, as appropriate, until the condition is corrected. The roadside inspection OOS rates for 2015 were retrieved from the [FMCSA website](#), accessed December 27, 2016.

⁵⁰ A focused crash investigation is a preliminary tool used by the FMCSA to evaluate the driver, vehicle, and motor carrier for potential compliance issues. Noncompliance could result in additional FMCSA interventions.

Greyhound provides paper-based directions to drivers who are assigned new routes. The directions for route 6876 suggest that drivers departing from Gilroy take US-101 north to Interstate 280 north, not SR-85, to reach the San Jose bus terminal. According to those directions, the driver should have remained on US-101 for another 8 miles (green route in figure 11).⁵¹ Instead, on the day of the crash, the driver said that he had intended to take the left exit HOV lane for SR-85 (yellow route in figure 11). Five days earlier, based on data obtained from Cadec, a fleet management system, the driver had taken the right exit (non-HOV) lanes for SR-85 (blue route in figure 11).⁵²

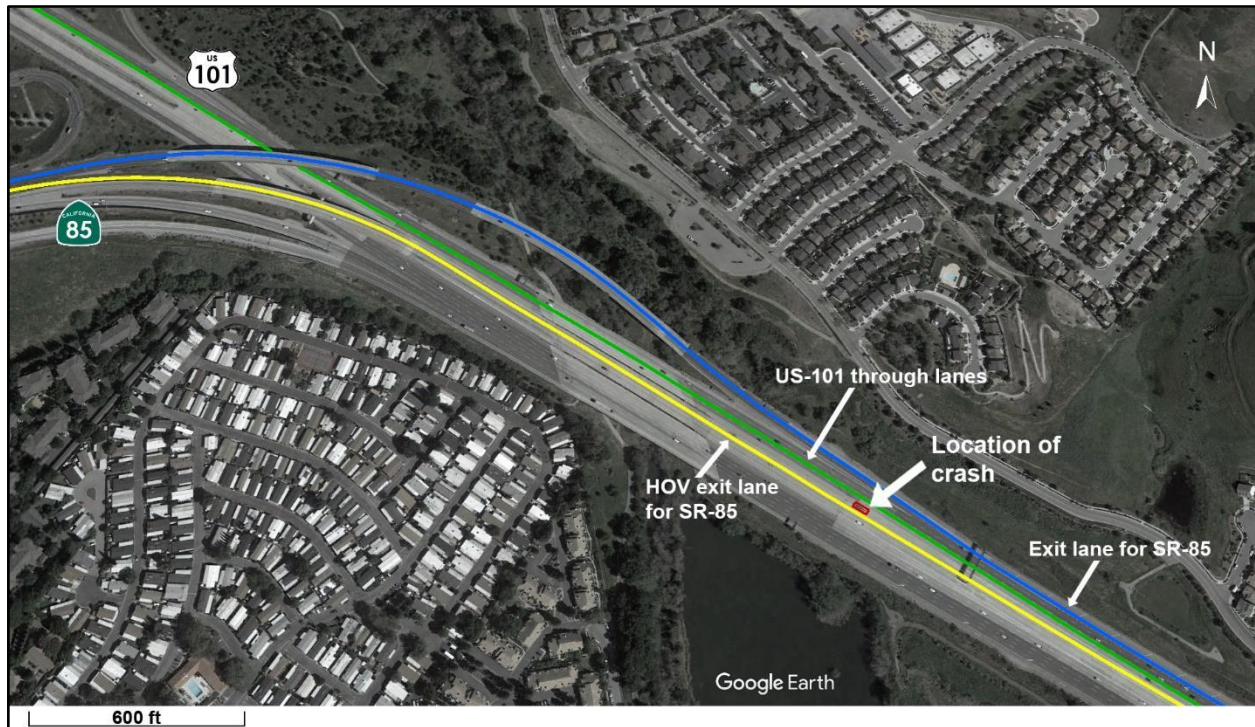


Figure 11. US-101–SR-85 interchange showing crash location: yellow line marks driver's intended route on day of crash, blue line marks driver's route 1 week prior to crash, and green line marks Greyhound-prescribed route. (Source: Google Earth, depicting crash location on January 26, 2016)

NTSB investigators separately queried the Los Angeles terminal manager and the Greyhound corporate director of safety and security regarding the carrier's routing policy. Drivers are instructed that they may deviate from the provided directions to account for traffic delays or if a more expedient route is known. Greyhound acknowledged that this practice is

⁵¹ The directions for route 6876 did not include travel on SR-85, and Greyhound initially stated that SR-85 was not an approved alternate path for this route. In October 2016, Greyhound provided NTSB investigators with additional information for other northbound routes. Some of these other routes do include travel on SR-85, suggesting that the carrier did not consider SR-85 to have any inherent characteristics that present an increased crash risk for motorcoaches. SR-85 was simply not the approved alternate path for the route on which this crash occurred.

⁵² Cadec is a fleet management tool that allows a carrier to track the location of vehicles while en route. The bus involved in this crash was equipped with a Cadec S200 system.

contrary to its driver's rulebook, which states: "Drivers must know the routes and stations in their assigned service. Drivers shall not deviate from the route prescribed by the Company, except in emergency situations, which must be reported to a supervisor."

Like the rulebook, the routing policy requires drivers to report route deviations to their supervisors. According to Greyhound records, the driver did not report his intention to take an alternate route during this trip, or that he had taken an alternate route when passing through the interchange on January 14, 2016. According to Greyhound, the carrier does not monitor GPS data for route deviations.

1.8.4 Driver Personnel Records

As required by 49 *CFR* 391.51, the Greyhound corporate office maintains driver qualification files.⁵³ According to Greyhound, home terminals maintain driver personnel records in a paper file system—which should contain all official actions, such as commendations, accident reports, and suspensions. Corporate safety officials have no immediate access to personnel records; they must request copies from the driver's home terminal.

Greyhound provided NTSB investigators with the accident driver's personnel records from 2001 to 2015. Upon inspection, the records for 2002–2005 were determined to be either missing or incomplete. Greyhound representatives attempted to recreate the missing records by reviewing separate disciplinary, award, and accident records.⁵⁴ Between August 2001 and March 2015, the driver was subject to 27 disciplinary actions, 19 of which resulted in temporary suspensions (see table 3).

⁵³ Driver qualification files typically include, at minimum, the driver's employment application; motor vehicle record obtained within 30 days of hire, and annually after hiring; certificate of road test or equivalent; CDL; and medical certification.

⁵⁴ NTSB investigators cannot be confident that the recreated records are complete and include all official records.

Table 3. Summary of bus driver's disciplinary record, August 2001–March 2015.

Date	Reason	Refresher Training Received ^a	Days of Suspension
08/14/01	Preventable accident	Postaccident	4
11/08/01	Preventable accident	Postaccident	3
02/18/02	Preventable accident	--	4
06/13/02	Late to work	--	3
07/01/05	Failure to show	--	3
07/26/05	Mystery rider violation ^b	--	Warning only
05/05/06	No show for run	--	7
09/16/06	Mystery rider violation	--	7
01/16/08	HOS violation	Log refresher	2
07/15/08	HOS violation	--	Warning only
12/21/09	Preventable accident	Postaccident	2
03/03/10	Violation of company policy	--	2
07/25/10	Speeding	"Stay sharp" refresher	Warning only
09/23/10	Speeding	--	Warning only
12/02/10	Late to report for random drug test	--	Termination
03/26/11	Backing up collision	Postaccident	2
09/25/11	Speeding (83 mph)	--	Warning only
10/26/11	HOS violation	--	Warning only
01/14/12	Speeding	--	2
08/06/12	HOS violation	--	Warning only
09/24/12	Speeding	--	4
10/09/12	HOS violation	--	Warning only
12/01/12	Failing to comply with company rule and 49 <i>CFR</i> 391.43 violation ^c	--	1
02/07/13	Speeding	--	2
04/01/13	Speeding	--	4
07/04/13	Speeding	--	2
10/22/13	Cell phone violation	--	2
03/01/15	Speeding ^d	--	2

^a Each refresher training is matched with the specific violation if it occurred within a month of such. The driver also received refresher training following other events not included in this table, such as part of a return-to-duty process.

^b In this program, a compensated passenger—trained in safety protocols and unknown to the driver—observes and rates the driver's performance across 29 safety performance metrics.

^c The driver used incorrect procedures on the medical certification forms.

^d This speeding citation was received during a roadside inspection. The Cadec system detected other speeding violations in this table when the driver was traveling on freeways at a speed of 73 mph or greater.

The bus driver received refresher training following most of the crashes documented in his personnel record.⁵⁵ However, since July 2010, he had received refresher training following only one of nine speeding violations.

Greyhound stated that it does not have a policy that establishes a threshold for the number of suspensions a driver may incur before being terminated. The Greyhound contract with the Amalgamated Transit Union limits the scope of infractions and the period of time that can be considered for disciplinary actions, including terminations. However, the limited time provision does not apply to safety-related violations. The contract states:

When disciplining employees, complaints, discipline or records, which have been brought to the attention of the Company 24 months prior to the incident, will not be used to determine guilt or penalty. This provision will not apply to safety related activities, including speeding violations, chargeable accidents (only preventable accidents will be charged against the driver's record), damage to property, personal injury, and use of alcohol or illegal substances.

Greyhound began introducing DriveCam systems into its fleet in 2013. Since then, the driver accumulated 18 critical events—each of which involved hard braking or electronic stability control activation. In May 2015, the driver was included in the Greyhound “top 20” list of drivers who represent the worst offenders based on the accumulation of critical DriveCam events.⁵⁶ Subsequently, he received a warning and a coaching session to improve the following identified safety deficiencies: “safety following distances” and “maintaining a space around vehicle.” Table 4 summarizes the critical DriveCam events for the driver.

During an interview with NTSB investigators, the driver's supervisor—who supervised him for 4 years—stated that he was a responsible employee. Although he remembered coaching the driver for DriveCam violations in the past, he could not recall any recent disciplinary actions or coaching corrections involving the driver.

According to Greyhound, based on its agreement with the driver union, DriveCam is not a disciplinary tool but rather a coaching tool to help improve performance.

⁵⁵ Greyhound records show that the driver received postaccident training on October 31, 2013, but his personnel records do not indicate that he was involved in a crash at that time.

⁵⁶ The “top 20” lists are generated quarterly and include drivers with the highest risk scores as calculated by the DriveCam system.

Table 4. Summary of bus driver's history of critical DriveCam events.

Date	Reason for "Critical Event"	Risk Score ^a	Comments ^b
09/25/13	Hard braking	8	Distracted
10/04/13	Hard braking	8	Failed to keep out ^c
10/22/13	Stability control	0	Cell phone in hand while turning
12/07/13	Hard braking	0	Obstructed view
05/13/13	Hard braking	3	Distracted
05/23/14	Hard braking	5	Too fast for conditions
05/20/14	Hard braking	0	Light changed, no impact
06/06/14	Hard braking	4	Poor awareness
07/12/14	Hard braking	0	Cell phone, hands free
11/13/14	Hard braking	10	Unsafe risky violation
12/01/14	Hard braking	5	Too fast for conditions
12/09/14	Hard braking	4	Poor awareness
12/03/14	Hard braking	4	Late response
01/22/15	Hard braking	0	Unbelted, no seat belt
02/11/15	Hard braking	4	Poor awareness
03/03/15	Rough road	3	Rolling stop
04/08/15	Hard braking	0	Possible collision
05/12/15	Hard braking	2	Following too close
11/28/15	Hard braking	8	Failed to keep out, distraction/eating
12/03/15	Hard braking	4	Late response

^a The DriveCam system automatically calculates the risk score, in which "0" indicates an event with no meaningful risk of collision and "10" an event with considerable risk.

^b These notes were documented by Greyhound at the time of event reporting.

^c "Failed to keep out" indicates an event in which the driver did not keep sufficient space from the forward vehicle.

1.9 Collision Avoidance System Testing

A forward collision avoidance system (CAS) is a driver assist technology that detects a forward conflict and alerts the driver, and, if necessary, automatically applies the brakes. As such, for the purposes of this report, CAS consists of at least two components: a collision warning system (CWS) and autonomous emergency braking (AEB). Although motorcoaches are not required to be equipped with CWS or AEB, about 20 percent of Greyhound buses were equipped with at least one of these systems at the time of the crash. However, the bus involved in this crash had neither system.

NTSB investigators—in collaboration with representatives from Greyhound, Meritor Wabco, and Energy Absorption Systems—conducted testing to determine the potential

effectiveness of CAS in mitigating this crash.⁵⁷ The testing was conducted on a 9,000-foot-long section of a test track, using a truck-tractor equipped with a Meritor Wabco OnGuard Active collision mitigation system and a modified REACT 350 crash attenuator.⁵⁸ OnGuard—a radar-based system—includes a CWS component that warns the driver of an impending forward collision and an AEB component that initiates braking if the driver fails to respond to the initial warning.

The testing included the truck-tractor traveling at different speeds and approaching the crash attenuator with and without the retroreflective object marker or type I barricade. The CWS and AEB were tested under the following conditions:

- Speeds of 20, 40, and 55 mph.
- Retroreflectivity of the crash attenuator:
 - Lead cylinder with retroreflective object marker but without type I barricade.
 - Lead cylinder without retroreflective object marker but with type I barricade in front.
 - Lead cylinder without retroreflective object marker and without type I barricade.

Each of the nine conditions was tested twice, and the timing of the CWS onset and the AEB activation was recorded.⁵⁹ Timing was expressed as (1) the distance from the lead cylinder at the time of onset of the warning or activation of braking; and (2) the time to contact (TTC), which refers to the time before impact with the cylinder based on the direction and speed of the vehicle. The testing showed that OnGuard detected the crash attenuator in 18 of 19 trials.⁶⁰ The onset of the warning occurred 2.00–2.75 seconds TTC, and the AEB activated 1.15–1.70 seconds TTC. Table 5 summarizes the activations for all conditions.

⁵⁷ Meritor Wabco was the CAS supplier for MCI, the manufacturer of the accident bus.

⁵⁸ (a) Because of its immediate availability, a 2014 Freightliner truck-tractor, instead of an exemplar motorcoach, was used in the testing. Although the effectiveness of the AEB system may differ on a truck-tractor compared with a motorcoach, the system's capacity to detect a forward hazard remains the same. For further discussion, see section 2.6. (b) Instead of the complete REACT 350, only lead cylinders—one with the retroreflective object marker and one without—were used in the testing.

⁵⁹ The test at 40 mph in the second retroreflectivity condition was performed three times—two more times after the initial trial, in which the OnGuard system did not detect the cylinder.

⁶⁰ Because of the lack of movement in the environment, which activates the system, OnGuard went into the sleep mode during one trial. As a result, the system was inactive and did not detect the cylinder.

Table 5. Results of collision avoidance testing showing activations of forward CWS and AEB components of Meritor Wabco OnGuard Active collision mitigation system.

Speed (mph)	Retroreflectivity Condition	Collision Warning System		Autonomous Emergency Braking		
		Distance (feet)	TTC (sec) ^a	Distance (feet)	TTC (sec)	Speed Reduction (mph) ^b
20	With retroreflector	75.5	2.30	43	1.25	9.9
20	With retroreflector	72.2	2.35	12	1.25	13.0
40	With retroreflector	144.4	2.45	27	1.50	9.9
40	With retroreflector	154.2	2.70	19	1.40	11.2
55	With retroreflector	177.2	2.15	43	1.70	9.9
55	With retroreflector	206.7	2.60	42	1.65	8.4
20	Without retroreflector, with temporary barricade	75.5	2.40	8	1.30	13.5
20	Without retroreflector, with temporary barricade	72.2	2.35	11	1.15	12.9
40	Without retroreflector, with temporary barricade	N/A ^c	N/A	N/A	N/A	N/A
40	Without retroreflector, with temporary barricade	160.8	2.70	20	1.35	11.0
40	Without retroreflector, with temporary barricade	118.1	2.00	28	1.50	8.1
55	Without retroreflector, with temporary barricade	170.6	2.15	42	1.70	8.3
55	Without retroreflector, with temporary barricade	170.6	2.05	42	1.65	9.0
20	Bare cylinder	68.9	2.25	10	1.15	12.4
20	Bare cylinder	65.6	2.10	11	1.20	10.6
40	Bare cylinder	124.7	2.15	27	1.50	10.6
40	Bare cylinder	164.0	2.75	19	1.25	9.2
55	Bare cylinder	203.4	2.55	36	1.50	6.7
55	Bare cylinder	203.4	2.55	43	1.70	10.2

^a TTC = time to contact.^b The driver of the truck-tractor used in the testing steered away from the cylinder at the last moment, which disengaged the AEB. Thus, the AEB speed reduction does not represent the maximum possible reduction before impact.^c N/A = system did not detect the cylinder.

1.10 Weather

Historical data from the weather observatory at Mineta San Jose International Airport, located 11 miles north of the crash site, indicated that—on January 19, 2016, at 6:53 a.m.—the temperature was 55°F, with wind direction from the east–southeast at 20 mph; and the visibility was 8 miles, with hourly precipitation of 0.07 inch. Weather reports indicated that rainfall intensity at the time of the crash was moderate to heavy. According to motorist witnesses and emergency responders, the rainfall was steady and required the constant use of windshield wipers. Civil twilight began at 6:51 a.m.—14 minutes after the crash, indicating that the crash occurred in darkness. Wind gusts of 22–28 mph were reported. In the 44 days between the crash on December 6, 2015, and this crash, there were 21 days in which wind gusts were greater than 21 mph, the highest being 40 mph on December 13, 2015.⁶¹

NTSB investigators observed the pavement on January 22 during periods of heavy rain. The pavement drained well, and no ponding was observed.

⁶¹ The historical wind gust information was retrieved from [The Weather Company website](#), accessed December 27, 2016.

2 Analysis

2.1 Introduction

The crash sequence began when a Greyhound bus traveling northbound on US-101 near San Jose, California, entered a 990-foot-long unmarked gore, continued traveling for about 8 seconds at 61–56 mph, and struck an unmarked crash attenuator and a concrete barrier. Two passengers died, and the driver and 13 passengers were injured.

The analysis portion of this investigative report discusses why the bus driver was traveling in the gore area between the left exit HOV lane for SR-85 and the US-101 HOV lane, and why he did not make any avoidance maneuvers before striking the crash attenuator and the concrete barrier. Additionally, we discuss and issue recommendations in the following safety areas:

- Highway
 - Repair of traffic safety devices
 - Sign and roadway markings
- Managing driver risk
- Occupant protection
 - Maintenance of passenger restraint systems
 - Pretrip briefing and use of restraint systems
- Collision avoidance systems.

As a result of this investigation, the NTSB established that the following factors did not contribute to the cause of the crash:

- ***Driver licensing or driving experience:*** The bus driver held a current CDL with appropriate endorsements and had more than 2 decades of driving experience.
- ***Driver distraction, substance impairment, or medical conditions:*** The examination of video evidence showed no indication of distraction. Postcrash toxicology tests revealed that the bus driver did not use alcohol or other drugs prior to the crash. Although the driver had poorly controlled diabetes, there is no evidence that his diabetic condition and the resultant peripheral neuropathy affected his ability to safely operate the bus. Decreased sensation in the feet, resulting from diabetic peripheral neuropathy, could affect a person's ability to effectively apply brakes; however, the driver did not brake at all. Additionally, diabetes has the potential to affect vision. Although NTSB investigators were unable to evaluate the driver and could not determine if diabetes impaired his vision, even a driver with normal visual acuity could not have perceived the unmarked crash attenuator in time to avoid the crash

(see section 2.2). There is no evidence to suggest that the driver's diagnosed peripheral neuropathy or potential diabetic retinopathy contributed to the crash.

With respect to potential driver fatigue, NTSB investigators were unable to determine the amount of sleep, if any, that the driver had obtained in the 24 hours prior to the crash. However, video evidence showed that the driver appeared to be alert in the moments preceding the crash.

- **Vehicle:** NTSB investigators examined the bus and found no preexisting mechanical conditions that would have contributed to the circumstances of the crash. Based on the weather and roadway conditions, the speed of the bus, and the tread depth of its tires, NTSB investigators found no evidence that the vehicle could have experienced hydroplaning at the time of the crash.

The NTSB, therefore, concludes that none of the following were primary or contributory factors in the crash: (1) driver licensing or experience; (2) driver distraction, substance impairment, or medical conditions; or (3) mechanical condition of the bus.

First responders provided appropriate and efficient emergency medical services, and followed applicable communication and command handover protocols. The NTSB, therefore, concludes that the emergency response to this crash was timely and effective.

2.2 Precrash Environmental and Roadway Conditions

The crash occurred in darkness during the early morning commute. Continuous moderate-to-heavy rain required the use of windshield wipers. Nighttime precipitation can restrict a driver's forward visibility and limit the effective distance of headlights by absorbing and scattering emitted light (Edwards 1999; Bullough and Mark 2001). Further, rain reflects some light back to the driver, causing glare and reducing contrast. Rain on the windshield also scatters the light emitted by traffic, further exacerbating glare. Under these conditions, a driver would have more difficulty detecting and perceiving impending hazards. The NTSB concludes that darkness and precipitation restricted the bus driver's forward visibility.

The crash attenuator lacked any retroreflective properties, because it was missing a critical component—the retroreflective object marker on the lead cylinder. Visual examination of recordings from the forward- and inward-facing cameras on the bus showed that (1) the attenuator was not clearly visible until less than 1 second before impact, and (2) the driver appeared to be unaware of the approaching attenuator and the concrete barrier. Even in the last frame of the recording before impact, the driver appears to be alert and shows no indication that he has detected the imminent hazard.

At the request of NTSB investigators, Michigan Technological University conducted a saliency/conspicuity study of still images extracted from the recording of the forward-facing camera. In the seconds before the crash, the environment around the crash attenuator includes numerous lights from surrounding vehicles and reflected light on the wet pavement—all of

which are more salient than the lead cylinder of the crash attenuator (see figure 12).⁶² As such, the lead cylinder was unlikely to capture the driver's attention in time to avoid the crash, particularly considering his lack of expectation of a forward hazard.



Figure 12. Still image from forward-facing DriveCam video recording, captured 2 seconds before impact, with exit sign located behind last cylinder of crash attenuator.

The NTSB concludes that under the environmental conditions at the time of the crash, the crash attenuator without the retroreflective object marker on the lead cylinder could not have been perceived by the bus driver in time to avoid the crash.

Examination of the recording from the inward-facing DriveCam camera showed that the driver made a deliberate move into the gore area about 8 seconds before impact. Based on the speed of the bus, the driver's head position, and the lack of steering, it does not appear that he had intended to change lanes after establishing his position in the gore. The driver's interview with CHP suggests that he believed he was in a travel lane. He expressed confusion about the sudden appearance of barrels on the roadway and the number of left exit HOV lanes.

⁶² (a) Each still image was analyzed using the Itti and Koch (2000) saliency model in the saliency toolbox for Matlab (Walther and Koch 2006). This model is purely a bottom-up model of visual search. It relies only on environmental characteristics to determine areas of interest. It does not consider driver expectations. The toolbox produces a saliency map that depicts regions of interest along several dimensions of contrast, including color, intensity, and line orientation. The saliency of each area is based on the contrast between that area and its immediate surroundings. See the report on measuring saliency in crash site images in the NTSB public docket for this investigation. (b) The still images contain rain droplets that were not present in most of the driver's field of view because of the motion of the windshield wipers. Even when excluding the areas around the rain droplets during image processing, more than a dozen other areas are still more salient than the black cylinder. For additional information, see the report on measuring saliency in crash site images in the NTSB public docket for this investigation.

The absence of any delineation on the crash attenuator or on the inside of the gore offers one explanation for the driver mistaking the gore for a travel lane. The driver's previous trip, 4 days earlier—in which he exited on the right side—provides an additional explanation for his error. As shown in figure 6, the right exit for SR-85 has two lanes, with the inner lane branching off the US-101 lane about 200 feet before the exit. Because the driver had experienced two exit lanes on the right side, he may have anticipated a similar configuration for the left exit. The NTSB concludes that the bus driver may have had an inaccurate expectation of the SR-85 left exit configuration.

At the time of the crash, the driver had deviated from two Greyhound policies. He took an alternate route of travel without notifying Greyhound; and he did not fully adhere to the carrier's adverse weather driving policy. The driver was traveling at an average speed of 59 mph before entering the gore and 56 mph at the time of impact—below the speed limit of 65 mph and within the flow of traffic.⁶³ But, according to Greyhound policy, he should have reduced his speed by 25 percent, to 49 mph.⁶⁴ Although a slower moving bus would have resulted in reduced impact speed, it would not have affected the driver's latency in perceiving the unmarked crash attenuator.⁶⁵

The NTSB concludes that, despite deviating from Greyhound policies and possibly having an inaccurate expectation of the left exit configuration, the bus driver would not likely have followed an incorrect travel path had the crash attenuator included the retroreflective object marker.

2.3 Highway Issues

2.3.1 Repair of Traffic Safety Devices

As a result of a similar collision at this location on December 6, 2015, the retroreflective object marker was displaced. Within 24 hours of the crash, as per its policy, Caltrans had cleared the crash scene. Workers placed two temporary type I barricades in front of the reset crash attenuator—but they did not install a retroreflective object marker on the lead cylinder. The temporary barricades were intended to delineate the crash attenuator until installation of the marker. Caltrans policy requires that any repair to a crash attenuator be completed within 7 days.

However, 44 days later—up to the morning of the January 19, 2016, crash—the lead cylinder of the crash attenuator was still missing its retroreflective object marker. Moreover, the two temporary barricades were displaced and were not visible to the driver, leaving the attenuator without any delineation.

⁶³ The video from the forward-facing DriveCam camera shows the bus moving at the speed of, or slower than, other vehicles; and the Caltrans real-time traffic-monitoring station shows an average vehicle speed of 56.6 mph at the time and in the vicinity of the crash location.

⁶⁴ A 25 percent reduction of the 65-mph speed limit equates to a maximum allowable speed of 48.75 mph.

⁶⁵ The video from the inward-facing camera does not show that the driver perceived the hazard at any point prior to impact. At 56 mph, a vehicle travels 50 feet in 0.61 second; at 49 mph, it travels 50 feet in 0.69 second. The additional 0.08 second in the last 50 feet before impact would not have affected the driver's ability to perceive the hazard earlier.

Although the temporary barricades met the MUTCD standard pertaining to the size of the retroreflective area and were ballasted beyond minimum requirements, they were incapable of withstanding the environmental conditions at the crash site. Wind gusts in the area of the crash were greater than 21 mph roughly every other day since placement of the temporary barricades, which exceed their stability limit at 18–21 mph. Because Caltrans did not inspect the temporary barricades, it is unknown when they became displaced.

Several days after placement of the temporary barricades—on December 11, 2015—a Caltrans maintenance crew supervisor reported locating a retroreflective object marker.⁶⁶ However, Caltrans personnel did not install the marker, reportedly due to scheduling conflicts and holidays.

Caltrans uses an electronic system, the IMMS, to track work orders. However, the IMMS does not track the completion of orders; it indicates only the initiation of repair. As such, unless the order specifies that work is not complete, a job completed in a single day can be indistinguishable from repair work done in stages and over several days. Neither does the IMMS provide reminders of overdue work orders. In fact, the December 6, 2015, work order did not even mention that an object marker was required to complete the repair. Furthermore, Caltrans did not complete a repair checklist for the crash attenuator, as per its policy regarding the repair of proprietary devices. The absence of the checklist should have alerted the district safety devices coordinator to investigate the status of the repair and the associated checklist. The NTSB concludes that an inadequate work order tracking system contributed to Caltrans not completing the necessary repairs to the crash attenuator.

If the IMMS had required a notation that an object marker had been ordered, but not installed, the supervisors, superintendents, and district safety devices coordinator could have reminded the work crews that the order was not complete. A system that automatically sends reminders about incomplete orders would have been even more effective.

The NTSB concludes that had Caltrans used an order tracking system that showed the progress of work orders and provided reminders for those that were overdue, it would have been less likely to neglect to complete the repair of the crash attenuator. The NTSB therefore recommends that Caltrans modify its work order tracking system to show completion status and to include a means of providing reminders when work orders, particularly those for proprietary devices, are overdue or incomplete.

⁶⁶ It is unclear whether the assembly was “ordered” or “immediately available for installation.”

2.3.2 Sign and Roadway Markings

2.3.2.1 Signage. For a 2007 crash investigation in Atlanta, Georgia, in which a bus driver mistook a left exit lane for an HOV through lane, resulting in seven fatalities, the NTSB issued two recommendations to the FHWA pertaining to left exit signs (NTSB 2008). Safety Recommendations H-08-3 and -7 requested that the FHWA amend the MUTCD to require that left exit signs, particularly at left HOV exits, include a “LEFT” plaque atop.

As a result of the Atlanta crash and these two recommendations, the FHWA proposed new requirements for HOV guide signs and guidance for pavement markings. The FHWA acknowledged that freeway drivers might confuse left exits with HOV lanes. Left-side exits, in general, tend to violate driver expectations because of their infrequency. However, left exit HOV lanes also minimize the risks associated with lane changes and highway merging.

In 2009, the FHWA revised the MUTCD and included new standards pertaining to left exit and preferential lane signage. The compliance date for the ruling was December 31, 2014. As shown in the left image of figure 13, the sign for the left exit HOV lane for SR-85 was out of compliance with the MUTCD standard for left exit plaques; the “LEFT” plaque should have been added to the top of the sign by December 31, 2014.⁶⁷ As an existing sign at the time of the MUTCD revision, though it lacked the full border on top indicating a preferential lane (that is, “HOV EXIT”), it was not out of compliance for that standard. A replacement sign at that location without the full border indicating a preferential lane would have been out of compliance for the standard. The right image in figure 13 depicts a compliant sign presenting the same information.

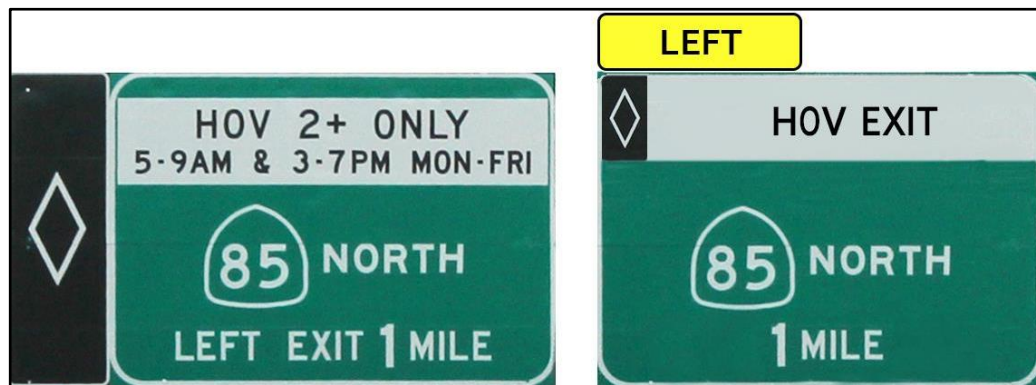


Figure 13. Sign for left exit HOV lane at crash location (left) and example compliant sign (right).

As of March 2017, Caltrans had not updated the sign for the left exit HOV lane at the crash location to comply with MUTCD guidelines. The NTSB concludes that had the sign for the left exit HOV lane for SR-85 been in compliance with the MUTCD, it would have provided the bus driver with improved traffic guidance and may have prevented the crash. Therefore, the NTSB recommends that Caltrans add the left exit plaque to the left exit sign at the crash location and to all left exit guide signs on California highways, as required by the FHWA.

⁶⁷ All three guide signs on approach to the crash location were out of compliance with the MUTCD requirements pertaining to left exit plaques.

The FHWA can assist in expediting California's compliance with this requirement through additional discussion with Caltrans and, if necessary, by instituting penalties.⁶⁸ The NTSB concludes that the FHWA has a vital role in ensuring that Caltrans expedite its compliance with the requirements of the MUTCD. Therefore, the NTSB recommends that the FHWA assist Caltrans in complying with the MUTCD requirement pertaining to plaques for left exit signs.

2.3.2.2 Gore. The inside area of the gore was not marked with optional diagonal cross-hatching or chevrons. However, the FHWA does not require, or even recommend, such markings. The MUTCD provides only optional guidance. Section 3B.24 states: "Chevron and diagonal crosshatch markings may be used to discourage travel on certain paved areas, such as shoulders, gore areas, flush medians between solid double yellow center line markings or between white channelizing lines approaching obstructions in the roadway"

Similarly, the California MUTCD also provides optional guidance.⁶⁹ Chevrons may be used in a gore area to add emphasis but only when so determined by a district traffic engineer. In response to an inquiry from NTSB investigators about the lack of chevrons to delineate the gore, the Santa Clara Valley Transportation Authority, which designed the US-101–SR-85 interchange at the request of Caltrans, indicated its determination that the gore complied with existing guidance.⁷⁰

California's decision-making process regarding delineation of the neutral area of gores follows MUTCD guidelines. Local district traffic engineers make the determination after considering traffic volume, speed limit, crash history, roadway geometry, and gore dimensions. However, a decision made at the time of highway construction—whether to use chevrons or diagonal cross-hatching—is not regularly revisited. Yet, factors that affect that decision, such as traffic volume and crash frequency, can change significantly over time. For example, the crash location has been the scene of eight crashes over the past 8 years.

Left-side exits have a higher crash risk, particularly for severe crashes (Chen and others 2011). Combined with the relatively high rate of crashes at the US-101–SR-85 interchange, this factor highlights the location as an area that could benefit from improved traffic guidance.

The NTSB concludes that the absence of optional pavement markings in the neutral area of the gore—in combination with the nonretroreflective crash attenuator—contributed to inadequate traffic guidance, which led to the bus driver's error in not following the correct path onto the left exit HOV lane. Therefore, the NTSB recommends that Caltrans delineate the neutral area of the gore at the crash site using the best traffic guidance practices, such as chevrons or

⁶⁸ The FHWA can institute penalties to states for failing to comply with selected federal highway-related statutes. The types of statutes and the possible penalties are described in *Financing Federal-aid Highways*, FHWA-PL-07-017; see the [FHWA website](#), accessed December 5, 2016.

⁶⁹ The NCHRP indicates that 13 states require the use of chevrons or diagonal cross-hatching on exit gores. See [NCHRP synthesis 356](#) for more information, accessed March 28, 2017.

⁷⁰ Caltrans approved the highway design proposal. According to the transportation authority, Caltrans has accepted legal responsibility for design and maintenance of the US-101–SR-85 interchange.

diagonal cross-hatching. Additionally, the NTSB recommends that Caltrans revise the California MUTCD to change the delineation of left exit gores, such as by using chevrons or diagonal cross-hatching, from an optional to, at minimum, a recommended guidance practice.

The NTSB also recommends that the FHWA revise the MUTCD to change the delineation of left exit gores, such as by using chevrons or diagonal cross-hatching, from an optional to, at minimum, a recommended guidance practice.

2.4 Motor Carrier Issues

2.4.1 Managing Driver Risk

Effective driver risk management relies on infrastructure to implement safety practices and on control mechanisms to maintain those safety practices and evaluate their effectiveness. For example, the infrastructure might include programs to address driver fatigue, electronic logging systems to prevent HOS violations, or video monitoring systems to oversee driver performance.

At the request of the FMCSA, in 2007 the TRB synthesized the best safety practices of commercial carriers by examining safety-related components such as communication, evaluation of driver performance, use of technology, driver incentives, and knowledge of safety policies (TRB 2007). The safety practices discussed in the TRB report provide a roadmap for effective driver risk management.

Greyhound implements many of the TRB-recommended safety practices. The carrier's safety policy manual and driver's rulebook promote its core safety principles. Sections 2.4.2 and 2.4.3 of this report discuss the adequacy of the Greyhound driver risk management programs, such as advanced driver monitoring systems and control mechanisms for oversight of driver safety records.

2.4.2 Developing Driver Risk Management Programs

For a 1998 roadway departure crash investigation in Burnt Cabins, Pennsylvania—which resulted in seven fatalities—the NTSB issued four recommendations to Greyhound pertaining to the need for a fatigue management program, the use of traffic violations and complaints in driver assessment, and the adoption of electronic recording systems to enhance vehicle and driver oversight programs (Safety Recommendations H-00-6, H-00-7 and -9, and H-00-8, respectively; NTSB 2000).

Greyhound hired a consultant to develop a comprehensive fatigue management program that included identifying signs of fatigue and providing methods of reducing fatigue and sleep apnea. Additionally, the carrier restructured its routes to include commute time in hours of service—which is particularly relevant in this crash because of the driver's 3.5-hour commute—and addressed routes that require driver layovers. Because of these improvements, Safety Recommendation H-00-6 is classified "Closed—Acceptable Action."

Furthermore, Greyhound began incorporating traffic and logbook violations, as well as customer complaints, into its driver assessment program. In 2011, the carrier introduced the Cadec fleet management system to enhance vehicle and driver oversight programs. As a result, Safety Recommendations H-00-7, -8, and -9 are classified “Closed—Acceptable Action.”

Greyhound demonstrated a proactive approach to safety by introducing an event-based video recording system in 2013, for which it petitioned the FMCSA for an exemption to mount the video recorder on the windshield. The carrier cited multiple reasons for use of the DriveCam system, including enhancing passenger safety and identifying risky driving behaviors.⁷¹

By implementing these four NTSB recommendations and incorporating DriveCam into its fleet, Greyhound created a framework for managing driver risk. However, this investigation uncovered several deficiencies that prevent the carrier from obtaining the full benefits of its driver risk management programs—deficiencies that primarily relate to inadequate control mechanisms and the application of existing safety practices.

2.4.3 Implementing Driver Risk Management Programs

2.4.3.1 Record-Keeping. NTSB investigators determined that the driver’s personnel records were inaccurate and, in some instances, missing. What Greyhound offered as a complete personnel record—which should have included all official actions, such as commendations and suspensions—contained out-of-sequence and incomplete paper forms. Additionally, the record was missing information for a 5-year period, and some reported actions did not correlate with information from disciplinary records.

Inadequate record keeping prevents terminal managers from easily accessing driver records and accurately assessing driver performance. Indeed, the driver’s supervisor reported not recalling any disciplinary actions against the driver, while in the 4 years during which he supervised him, the driver was on 10 occasions disciplined for safety-related violations.

Because driver personnel records are stored locally, at home bus terminals—and only in paper format—they are inaccessible to corporate safety officials, unless specifically requested. The review of the personnel records of all drivers in one terminal, or across the fleet, could be a major undertaking. The Los Angeles terminal, for example, employs 133 drivers. Indeed, Greyhound was unable to fulfill a request from NTSB investigators for the average number of suspensions of other drivers in the Los Angeles terminal, further illustrating the limitations of its record-keeping system.

A paper-based record-keeping system restricts access to driver personnel documents. Each time the documents are handled—such as during regular CHP inspections of the Los Angeles terminal—an opportunity is created for them to be misfiled or lost. An electronic record-keeping system, with proper backup, would limit the loss of records and allow the carrier to set up automatic alerts and to easily examine trends.

⁷¹ See 74 *FR* 11807–11808, March 19, 2009.

Complete and readily available documents are essential to evaluate a driver safety record, which is one of the key components of effective driver risk management. However, the Greyhound records management structure afforded neither complete nor readily available documents.

The NTSB concludes that the inadequate maintenance and limited usability of Greyhound's paper-based record-keeping system resulted in the loss of documentation, made it difficult for terminal managers to easily access and evaluate driver performance, and prevented corporate safety officials from providing timely and adequate oversight.

Therefore, the NTSB recommends that Greyhound create a personnel file management system that, at minimum, (1) allows for driver records to be accessed by terminal and corporate officials; and (2) includes provisions and safeguards to ensure accuracy, security, backup, and proper maintenance.

2.4.3.2 Evaluation of Driver Performance. The NTSB investigation revealed that between 2001 and 2016, the bus driver was disciplined for 27 actions, including speeding and crashes. Nineteen of the disciplinary actions involved suspensions, for a total of 58 days. In the 2 years prior to this crash, the driver was reprimanded only once—for speeding, which resulted in a 2-day suspension. However, from 2012 to 2013, he had nine disciplinary actions, including five for speeding and one for violation of the carrier's cell phone policy, resulting in a total of 16 days of suspension.

For a speeding infraction in April 2013, the driver received a reprimand with a suspension and the following warning: "For these violations you will be suspended for 4 days with a final warning." The reprimand further stated: "Any future violations of any company regulations and/or policy will result in further disciplinary actions up to [and] including termination of employment with Greyhound Lines Inc."

Subsequently, the driver received additional speeding violations in July 2013 and March 2015, which resulted in further suspensions and almost identical "final" warnings. These violations did not result in increased disciplinary actions by the carrier. Actually, the last two warnings each resulted in a 2-day suspension—fewer days than the initial "final warning" in April 2013.

The driver's recompiled personnel record shows no speeding violations between 2001 and June 2010. However, since Greyhound acquired the Cadec system in 2010, it has reprimanded the driver for that infraction on nine occasions.⁷² Because of Greyhound's inadequate record-keeping, NTSB investigators were unable to compare the driver's speeding violations with those of other drivers in the Los Angeles terminal, or across the fleet. In 2013, Greyhound acquired another driver-monitoring system, DriveCam; and, since then, the driver has accumulated 15 critical events. On one occasion, in May 2015, he made the "top 20" list of worst offenders among all company drivers for that quarter. The carrier emphasizes that it uses

⁷² Although Greyhound fully integrated Cadec systems into its fleet in 2011, it started testing the systems in 2010.

DriveCam critical events only as teaching—not disciplinary—tools, as per agreement with the union.

Although the carrier may discipline or discharge drivers for violating corporate policies, as stated in the Greyhound driver’s rulebook, it does not have an established threshold for the number of suspensions that a driver may incur before termination. This deficiency—combined with inadequate record keeping—makes it unclear whether the driver’s safety violations were within the carrier’s acceptable limit to continue employment as a driver, or whether the carrier simply overlooked the previous suspensions when disciplining him for a new safety infraction.

Many passenger- or property-carrying commercial carriers have clear policies for the remediation of unsafe driver behavior. These safety policies contain corrective actions—such as training and coaching—as well as disciplinary measures. The type of corrective or disciplinary action varies in accordance with the severity of the driver infraction and its repeated occurrence within a specific period.

Among such carriers, the disciplinary measures are progressively applied. Typically, a driver receives a verbal warning as an initial attempt to correct unsafe driving behavior, followed by a written warning, and then a suspension for more serious or repeat infractions. If, after multiple attempts to remediate unsafe driving behavior through additional training and coaching, a driver continues to commit the same infractions, he or she is terminated.⁷³ By establishing and adhering to a clear policy regarding safety violations—particularly repeat infractions—carriers can maintain a consistent level of driver performance, and drivers are made aware of the consequences of their actions.

The NTSB concludes that though Greyhound had a proactive means of monitoring the unsafe behavior of its drivers, it had no clear policy regarding repeat infractions that provided specific steps to remediate the behavior or to justify termination. The NTSB recommends that Greyhound use industry best practices to establish a policy to more adequately address recurring unsafe driver behavior, to include effective remediation of behavior and establishment of suspension thresholds for termination.

2.5 Passenger Restraint System

Despite the presence of lap/shoulder belts on the bus, and the instructions for their use on each seatback, only two of the interviewed passengers reported using the belts. Both of these passengers were uninjured. Based on physical evidence, it does not appear that any of the other passengers used the belts, including the two passengers who were ejected and died.

The National Highway Traffic Safety Administration reports that 75 percent of occupants ejected from a vehicle sustain fatal injuries in such crashes (NHTSA 2009). Motorcoach crash and rollover tests with belted and unbelted crash test dummies have shown greater occupant retention within the seating compartment and increased injury mitigation for lap/shoulder-belted dummies (NHTSA 1999). In 2000, NHTSA conducted research showing that the installation of

⁷³ See the report on safety policies in industry in the NTSB public docket for this investigation for an example of a policy that includes specific disciplinary actions for each occurrence and each type of safety violation.

lap/shoulder belts in large buses would reduce the risk of fatal injuries in rollover crashes by 77 percent, primarily by preventing occupant ejection (NHTSA 2000)

In this crash, several bus occupants reported being thrown from their seats during the impact with the barrier and the subsequent rollover. One passenger was also partially ejected out a broken window. The NTSB concludes that had the lap/shoulder belts been properly worn by the bus passengers, they would have kept the occupants in their seats, prevented ejections, and reduced the risk of fatal and serious injuries. The NTSB further concludes that the lap/shoulder belts were effective in preventing injuries to those bus passengers who wore them.

In 2013, NHTSA issued a final rule—which went into effect in November 2016—requiring that all newly manufactured vehicles meeting motorcoach or over-the-road bus definitions be equipped with lap/shoulder belts at the driver and all passenger seating positions.⁷⁴ In support of this rulemaking, NHTSA estimated that even with a seat belt use rate of only 6 percent, the rule would be cost effective by preventing passenger ejections during crashes.

Six years before publication of the rule, in 2007, Greyhound’s parent company, First Group, initiated a program to develop and build a seat belt-equipped motorcoach passenger seat. Since 2009, all new Greyhound motorcoaches have been equipped with passenger lap/shoulder belts. By 2010, 20 percent of the Greyhound fleet was equipped with lap/shoulder belts in all seating positions.⁷⁵ As of December 2016, 50 percent of the carrier’s fleet was so equipped. The accident bus was a 2014 MCI motorcoach, factory-equipped with lap/shoulder belts in all seating positions.

Although Greyhound has been progressive in pursuing passenger safety systems in advance of the federal requirements for passenger lap/shoulder belts, this investigation identified two areas in which improvements should be made to obtain the maximum benefits of passenger lap/shoulder belts: maintenance and inspection of restraint systems, and pretrip safety briefings.

2.5.1 Maintenance and Inspection

Equipping buses with passenger lap/shoulder belts—combined with providing regularly scheduled maintenance and inspection—is critical to ensuring passenger safety. NTSB investigators found that several buckles were difficult to access because of their position below the seat. Even an exemplar bus provided by Greyhound had many seat belt buckles without covers and one inoperable seat belt buckle. As a result of these findings, Greyhound replaced the missing buckle covers and, in collaboration with IMMI, redesigned the seat belt stalk and buckle to retain accessibility and resist breaking. Although Greyhound has a policy requiring pretrip vehicle inspection, it does not explicitly require that the driver check passenger seat belts.

⁷⁴ See final rule, “Federal Motor Vehicle Safety Standards; Occupant Crash Protection,” at 78 *FR* 70416, November 25, 2013.

⁷⁵ The partner company IMMI began supplying Greyhound with Premier seats—with integrated lap/shoulder belts—in 2009. In 2010, the carrier ordered Premier seats for 213 new motorcoaches. See the [Greyhound press release](#), accessed December 28, 2016.

Since its inception, the NTSB has recognized the value of seat belts in buses. Following a 1968 crash in Baker, California, the NTSB recommended that the FHWA determine the necessity of regulations to require that passenger-carrying commercial operators install and maintain seat belts for the use of passengers and drivers (Safety Recommendation H-68-18; NTSB 1968).⁷⁶ Even in 2017, the safety needs remain the same: the proper use of restraint systems requires that they be operable and accessible.

The NTSB concludes that Greyhound maintenance and pretrip vehicle inspection procedures were incomplete with regard to passenger seat belts. Therefore, the NTSB recommends that Greyhound establish procedures to ensure that the seat belts on all buses are regularly inspected to maintain their functionality and accessibility.

2.5.2 Means of Increasing Seat Belt Use

2.5.2.1 Pretrip Safety Briefings. Educating passengers about the presence of restraint systems and the importance of their proper use is essential to increase seat belt use in buses. In a 1999 special investigation report on motorcoach issues, the NTSB issued a recommendation to the DOT to require motorcoach operators to provide passengers with pretrip safety information (Safety Recommendation H-99-8; NTSB 1999). Following a 2014 crash in Orland, California, in which the lack of a pretrip safety briefing contributed to 10 fatalities, the NTSB superseded Safety Recommendation H-99-8 with a more comprehensive recommendation to the FMCSA (NTSB 2015c):

H-15-14

Require all passenger motor carrier operators to (1) provide passengers with pretrip safety information that includes, at a minimum, a demonstration of the location of all exits, explains how to operate the exits in an emergency, and emphasizes the importance of wearing seat belts, if available; and (2) also place printed instructions in readily accessible locations for each passenger to help reinforce exit operation and seat belt usage.

The FMCSA responded that because of cost/benefit concerns, it supports voluntary adoption of safety briefings. However, the agency intends to proceed with an advance notice of proposed rulemaking to solicit input from stakeholders. The cost of implementing such a recommendation arguably is minimal, particularly considering that the FMCSA has already developed basic safety briefing guidelines, and has created brochures and audio instructions that are available free of charge to motor carriers.⁷⁷

On the crash trip, the driver did not conduct a briefing to inform passengers about the availability and benefits of seat belts. Although Greyhound has developed a safety briefing script, it only recommends that drivers conduct the briefing. The script contains the following

⁷⁶ At that time, the FHWA had the authority to regulate seat belt use on passenger-carrying commercial motor vehicles.

⁷⁷ The FMCSA offers free pretrip safety information for bus passengers, including safety brochures, posters, and audio instructions for safety briefings. Its website also has “Buckle Up!” safety brochures in English, Spanish, Chinese, French, German, Japanese, and Korean. See the [FMCSA website](#), accessed November 30, 2016.

information regarding occupant protection: “Also, many of our buses are equipped with seatbelts, please make sure to fasten your seatbelt. There are emergency exits at each window should you need to exit in case of an emergency”

Greyhound has the opportunity to take a leading role in ensuring that passengers obtain the maximum benefits of lap/shoulder belts. The basic purpose of a pretrip safety briefing is to inform and educate passengers about safety features on the bus. Such briefings can serve as simple reminders of the lifesaving benefits of seat belts and may increase the likelihood of their use.

Adopting a company policy on passenger seat belt use could further increase the efficacy of pretrip safety briefings. Although the briefing may take a few minutes of a driver’s time, even the basic promotion of such a policy would further increase the likelihood of occupants wearing their seat belts.

The NTSB concludes that a pretrip safety briefing on the availability and benefits of restraint systems may have increased the likelihood of more passengers using the seat belts. Therefore, the NTSB recommends that Greyhound provide pretrip safety briefings at all stops prior to departure when taking on new passengers, which describe the use of the emergency exits and the benefits of wearing seat belts.

Since the Orland crash, the NTSB has investigated four crashes involving passenger-carrying commercial vehicles—in Cranbury, New Jersey (2014); Davis, Oklahoma (2014); Seattle, Washington (2015); and Red Lion, Delaware (2014). Although in two of these crashes the commercial vehicles were equipped with passenger seat belts, none of the passengers were restrained (NTSB 2015a, 2015d, 2016a, 2016b, respectively).

With respect to this crash, neither Greyhound policies nor FMCSA regulations required the driver to provide a safety briefing—and he did not do so. Thus, the NTSB reiterates Safety Recommendation H-15-14 to the FMCSA.

2.5.2.2 Rate of Seat Belt Use and State Laws. State laws provide another approach for increasing seat belt use. Although the enforcement of seat belt use laws in motorcoaches may be challenging, even the promotion of such laws would educate passengers about the minimum requirements for safe operation of a motorcoach. Additionally, pretrip safety briefings would be more effective if they included a reminder to passengers that state law (if applicable) requires the use of seat belts.

The nationwide seat belt use rate was 90 percent in passenger vehicles in 2016, which is the highest rate in history (NHTSA 2016b). In the 34 states with a primary enforcement seat belt use law for at least the front seats, the average seat belt use rate was 92 percent, compared with 83 percent in the rest of the country. The seat belt use rate in New Hampshire—the only state without any mandatory seat belt use laws—was 69 percent in 2015 (NHTSA 2016c).

With regard to seat belt use in motorcoaches, the numbers are substantially lower. In a recent NHTSA report on the feasibility of retrofitting motorcoaches with passenger lap/shoulder belts, the agency noted a lack of statistics on the passenger seat belt use rate in motorcoaches in

the United States. The usage rate is estimated to be less than 15 percent in buses equipped with seat belts (NHTSA 2016a).

Seat belt use saves lives, regardless of the seating position or the vehicle. For more than 25 years, the NTSB has advocated legislation requiring the use of seat belts. As a result of a 2014 crash in Davis, Oklahoma—which caused four fatalities to ejected occupants and in which none of the passengers in the medium-size bus were restrained—the NTSB issued the following safety recommendation to the 50 states, the District of Columbia, and Puerto Rico (NTSB 2015d):

H-15-42

Enact legislation that provides for primary enforcement of a mandatory seat belt use law for all vehicle seating positions equipped with a passenger restraint system.

This recommendation was issued based on (1) the considerable research showing an increase in seat belt use (Beck and West 2011; Chen 2015) and a decrease in fatalities (Farmer and Williams 2004; Douma and Tilahun 2012) following the transition from secondary to primary enforcement; (2) the NHTSA rulemaking requiring seat belts on motorcoaches; (3) the lack of state seat belt use laws pertaining to passengers in motorcoaches and other buses equipped with seat belts; and (4) the very low rate of seat belt use by motorcoach occupants.

The overall status of Safety Recommendation H-15-42 is “Open—Await Response.” As of December 2016, California has a primary enforcement seat belt use law that applies to all seating positions in passenger vehicles. Passengers in motorcoaches are not required to be restrained. However, the limitations of this law have recently been re-examined. The California senate took up a bill on December 5, 2016, that would require passengers in buses equipped with safety belts to be properly restrained.⁷⁸ If enacted, this bill would amend the state’s seat belt use law to include motorcoaches.

State laws mandating the use of seat belts would significantly improve the effectiveness of pretrip safety briefings in increasing the likelihood of passengers using available restraints. A combination of education, pretrip briefings, and seat belt use laws would increase usage rates. For example, one of the largest carriers in Sweden reported motorcoach passenger seat belt use rates as high as 66 percent in 2015.⁷⁹ Since 2006, seat belt use has been mandatory in Sweden in all vehicles so equipped—and the government has also required pretrip safety briefings.⁸⁰

⁷⁸ The proposed bill (SB20) would amend section 34505.8 of the California Vehicle Code and add section 27315.2. For more information, see the [state of California website](#), accessed December 28, 2016.

⁷⁹ Swebus, a long-distance motorcoach carrier, surveyed 1,671 passengers on their use of seat belts. The information was obtained with assistance from researchers—who also translated the document—at VTI, the Swedish National Road and Transport Research Institute. See the [Swebus website](#), accessed October 17, 2016.

⁸⁰ On April 8, 2003, the European Parliament and Council issued Directive 2003/20/EC to member states to incorporate into their national laws a requirement to make seat belt use compulsory in all vehicles fitted with them. This directive amended Directive 91/671/EEC, which limited the compulsory use of seat belts to vehicles weighing less than 3.5 tons (motorcoaches exceed this weight) and to front seats only.

The NTSB concludes that the primary enforcement of mandatory seat belt use laws for all vehicles, in conjunction with pretrip safety briefings, could increase the rate of seat belt use in buses. Thus, the NTSB reiterates Safety Recommendation H-15-42 to the state of California.

2.5.2.3 Role of Associations. The American Bus Association (ABA) and the United Motorcoach Association (UMA) represent nearly 2,000 motorcoach companies across the United States. As one of the more progressive passenger-carrying companies, Greyhound had passenger lap/shoulder belts on all new motorcoaches 7 years before they were required, but it did not consider the importance of regular inspection of seat belts or mandatory pretrip safety briefings. It is unlikely that these issues are limited to Greyhound. The passengers of other motorcoach companies would also benefit from regular maintenance of seat belts and pretrip reminders of the benefits and proper use of the available occupant restraints.

The NTSB concludes that the benefits of regular maintenance and inspection of seat belts, as well as pretrip briefings, apply across the passenger-carrying fleet. Therefore, the NTSB recommends that the ABA and the UMA encourage member passenger-carrying companies to (1) establish procedures to ensure that the seat belts on all buses are regularly inspected to maintain their functionality and accessibility, and (2) provide pretrip safety briefings emphasizing the benefits of seat belt use.

2.6 Collision Avoidance Systems

The NTSB has advocated for various CAS technologies for more than 20 years. In the investigation of a 1995 multivehicle collision in Menifee, Arkansas, the NTSB recommended that the DOT test CWS in commercial vehicles (Safety Recommendation H-95-44; NTSB 1995). Since then, we have issued 19 recommendations pertaining to collision warning, adaptive cruise control, and AEB systems in both passenger and commercial vehicles. As part of this effort, the NTSB recently issued a special investigation report in which we examined advances in CAS technologies and issued the following recommendations to motorcoach manufacturers (NTSB 2015b):

H-15-8

Install forward collision avoidance systems that include, at a minimum, a forward collision warning component, as standard equipment on all new vehicles.

H-15-9

Once the National Highway Traffic Safety Administration publishes performance standards for autonomous emergency braking, install systems meeting those standards on all new vehicles.

Acknowledging that the CAS performance parameters in passenger and commercial vehicles may differ, the NTSB also issued the following safety recommendation to NHTSA (NTSB 2015b):

H-15-5

Complete, as soon as possible, the development and application of performance standards and protocols for the assessment of forward collision avoidance systems in commercial vehicles.

Safety Recommendations H-15-8 and -9 are classified “Open—Await Response” for MCI, and Safety Recommendation H-15-5 is classified “Open—Unacceptable Response.”

Although 20 percent of the Greyhound fleet is equipped with some type of CAS, the MCI bus involved in this crash had neither a CWS nor an AEB system. In a test scenario representing crash conditions, NTSB investigators showed that CAS would have been effective in preventing or mitigating the severity of the crash. The tested system detected the crash attenuator in 18 of 19 trials—and then provided a warning 2–3 seconds before impact and activated the AEB 1–2 seconds before impact. The testing was conducted on a CAS-equipped truck-tractor. The effect of AEB in motorcoaches may vary due to differences in design of the brake systems, but the benefits of CWS remain: the technology is clearly capable of detecting the stationary hazard and warning the driver in time to mitigate the consequences of the crash.

The NTSB concludes that had the bus been equipped with a CAS technology, it could have alerted the driver of the forward hazard in time to mitigate the severity of the crash. Therefore, the NTSB reiterates Safety Recommendations H-15-8 and -9 to MCI. To ensure that CAS components for commercial vehicles, particularly AEB, are manufactured to optimal performance standards, the NTSB also reiterates Safety Recommendation H-15-5 to NHTSA.

3 Conclusions

3.1 Findings

1. None of the following were primary or contributory factors in the crash: (1) driver licensing or experience; (2) driver distraction, substance impairment, or medical conditions; or (3) mechanical condition of the bus.
2. The emergency response to this crash was timely and effective.
3. Darkness and precipitation restricted the bus driver's forward visibility.
4. Under the environmental conditions at the time of the crash, the crash attenuator without the retroreflective object marker on the lead cylinder could not have been perceived by the bus driver in time to avoid the crash.
5. The bus driver may have had an inaccurate expectation of the State Route 85 left exit configuration.
6. Despite deviating from Greyhound policies and possibly having an inaccurate expectation of the left exit configuration, the bus driver would not likely have followed an incorrect travel path had the crash attenuator included the retroreflective object marker.
7. An inadequate work order tracking system contributed to the California Department of Transportation not completing the necessary repairs to the crash attenuator.
8. Had the California Department of Transportation used an order tracking system that showed the progress of work orders and provided reminders for those that were overdue, it would have been less likely to neglect to complete the repair of the crash attenuator.
9. Had the sign for the left exit high-occupancy-vehicle lane for State Route 85 been in compliance with the *Manual on Uniform Traffic Control Devices for Streets and Highways*, it would have provided the bus driver with improved traffic guidance and may have prevented the crash.
10. The Federal Highway Administration has a vital role in ensuring that the California Department of Transportation expedite its compliance with the requirements of the *Manual on Uniform Traffic Control Devices for Streets and Highways*.
11. The absence of optional pavement markings in the neutral area of the gore—in combination with the nonretroreflective crash attenuator—contributed to inadequate traffic guidance, which led to the bus driver's error in not following the correct path onto the left exit high-occupancy-vehicle lane.

12. The inadequate maintenance and limited usability of Greyhound's paper-based record-keeping system resulted in the loss of documentation, made it difficult for terminal managers to easily access and evaluate driver performance, and prevented corporate safety officials from providing timely and adequate oversight.
13. Although Greyhound had a proactive means of monitoring the unsafe behavior of its drivers, it had no clear policy regarding repeat infractions that provided specific steps to remediate the behavior or to justify termination.
14. Had the lap/shoulder belts been properly worn by the bus passengers, they would have kept the occupants in their seats, prevented ejections, and reduced the risk of fatal and serious injuries.
15. The lap/shoulder belts were effective in preventing injuries to those bus passengers who wore them.
16. Greyhound maintenance and pretrip vehicle inspection procedures were incomplete with regard to passenger seat belts.
17. A pretrip safety briefing on the availability and benefits of restraint systems may have increased the likelihood of more passengers using the seat belts.
18. The primary enforcement of mandatory seat belt use laws for all vehicles, in conjunction with pretrip safety briefings, could increase the rate of seat belt use in buses.
19. The benefits of regular maintenance and inspection of seat belts, as well as pretrip briefings, apply across the passenger-carrying fleet.
20. Had the bus been equipped with a collision avoidance system technology, it could have alerted the driver of the forward hazard in time to mitigate the severity of the crash.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the San Jose, California, crash was the failure of the California Department of Transportation to properly delineate the crash attenuator and the gore area, which would have provided improved traffic guidance. Contributing to the crash were the bus driver's error in entering the gore and the out-of-compliance signage, which affected traffic guidance. Contributing to the severity of the injuries was the lack of passenger seat belt use.

4 Recommendations

4.1 New Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following new safety recommendations:

To the Federal Highway Administration:

Assist the California Department of Transportation in complying with the *Manual on Uniform Traffic Control Devices for Streets and Highways* requirement pertaining to plaques for left exit signs. (H-17-2)

Revise the *Manual on Uniform Traffic Control Devices for Streets and Highways* to change the delineation of left exit gores, such as by using chevrons or diagonal cross-hatching, from an optional to, at minimum, a recommended guidance practice. (H-17-3)

To the California Department of Transportation:

Modify your work order tracking system to show completion status and to include a means of providing reminders when work orders, particularly those for proprietary devices, are overdue or incomplete. (H-17-4)

Add the left exit plaque to the left exit sign at the crash location and to all left exit guide signs on California highways, as required by the Federal Highway Administration. (H-17-5)

Delineate the neutral area of the gore at the crash site using the best traffic guidance practices, such as chevrons or diagonal cross-hatching. (H-17-6)

Revise the California *Manual on Uniform Traffic Control Devices for Streets and Highways* to change the delineation of left exit gores, such as by using chevrons or diagonal cross-hatching, from an optional to, at minimum, a recommended guidance practice. (H-17-7)

To the American Bus Association and the United Motorcoach Association:

Encourage member passenger-carrying companies to (1) establish procedures to ensure that the seat belts on all buses are regularly inspected to maintain their functionality and accessibility, and (2) provide pretrip safety briefings emphasizing the benefits of seat belt use. (H-17-8)

To Greyhound Lines, Inc.:

Create a personnel file management system that, at minimum, (1) allows for driver records to be accessed by terminal and corporate officials; and (2) includes provisions and safeguards to ensure accuracy, security, backup, and proper maintenance. (H-17-9)

Use industry best practices to establish a policy to more adequately address recurring unsafe driver behavior, to include effective remediation of behavior and establishment of suspension thresholds for termination. (H-17-10)

Establish procedures to ensure that the seat belts on all buses are regularly inspected to maintain their functionality and accessibility. (H-17-11)

Provide pretrip safety briefings at all stops prior to departure when taking on new passengers, which describe the use of the emergency exits and the benefits of wearing seat belts. (H-17-12)

4.2 Reiterated Recommendations

The National Transportation Safety Board also reiterates the following safety recommendations:

To the Federal Motor Carrier Safety Administration:

Require all passenger motor carrier operators to (1) provide passengers with pretrip safety information that includes, at a minimum, a demonstration of the location of all exits, explains how to operate the exits in an emergency, and emphasizes the importance of wearing seat belts, if available; and (2) also place printed instructions in readily accessible locations for each passenger to help reinforce exit operation and seat belt usage. (H-15-14)

To the National Highway Traffic Safety Administration:

Complete, as soon as possible, the development and application of performance standards and protocols for the assessment of forward collision avoidance systems in commercial vehicles. (H-15-5)

To the state of California:

Enact legislation that provides for primary enforcement of a mandatory seat belt use law for all vehicle seating positions equipped with a passenger restraint system. (H-15-42)

To Motorcoach Industries International, Inc.:

Install forward collision avoidance systems that include, at a minimum, a forward collision warning component, as standard equipment on all new vehicles. (H-15-8)

Once the National Highway Traffic Safety Administration publishes performance standards for autonomous emergency braking, install systems meeting those standards on all new vehicles. (H-15-9)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

T. BELLA DINH-ZARR
Acting Chairman

ROBERT L. SUMWALT
Member

CHRISTOPHER A. HART
Member

EARL F. WEENER
Member

Adopted: March 28, 2017

Member Weener filed the following statement.

Member Earl F. Weener
Statement in Concurrence
Submitted April 10, 2017

*Motorcoach Collision with Crash Attenuator in Gore Area, US Highway 101
San Jose, CA, January 19, 2016*

I offer this statement of concurrence with the report approved by the Board on March 28, 2017. I agree with my fellow Board Members that the cause of this tragic crash was both driver error and the lack of sufficient visual guidance to prevent, correct or mitigate his mistake. I feel, however, that there are several points which, due to the inherent time restrictions of a meeting, were not emphasized or discussed as thoroughly as could have been beneficial. To that end, I want to share the following points.

First, I want to emphasize the importance of thorough, recent medical records to NTSB investigations. Although staff, through diligent efforts to gather all available, relevant evidence, was able to determine the causes of this crash, these efforts were hampered by their inability to interview or examine the accident driver who declined to participate in the NTSB investigation. For various reasons, operators involved in accidents in all modes are often unwilling or unable to work cooperatively with staff during the course of an investigation. The availability of evidence from devices such as cameras and data recorders and other sources is crucial. As staff considers medical conditions which may have played a role in an accident, they can, even when an operator is unavailable, learn much from pre- or post-crash medical examination records.

In this crash, one may ask why this driver, of all the millions of others who passed the same way, did not avoid the dangers of the gore area. However, simply because a crash has yet to occur, does not mean there is no imminent danger. Staff correctly pointed out the poor weather conditions and driver's lack of familiarity with this route. Of note, this driver, an older individual, had medical conditions that may have placed him at a higher risk for vision related complications. In cases such as this, recent records of an examination can help staff rule in or out medical factors. For instance, such records for this driver might have helped explain his multiple previous driving incidents or his failure to exit US-101 at the appropriate, designated location. Unfortunately, no recent, comprehensive eye examination was discovered, and it is impossible to determine if this driver had some level of vision impairment on the morning of the crash. Without evidence, NTSB cannot establish medical causation. Regardless, I concur with staff and agree the failure to replace the retroreflector in a timely manner and the lack of clear markings, such as chevrons, in the gore area undoubtedly made the danger ahead less apparent to all drivers.

Second, I feel it is appropriate to emphasize the importance of medical fitness for every vehicle operator. Eye health is part of overall medical fitness. A vision test is only part of a comprehensive eye health examination. A comprehensive eye health examination can alert a driver to potential issues which may have future impacts on vision, particularly at night. As the Federal Motor Carrier Safety Administration works to promulgate regulations relating to commercial drivers with insulin treated diabetes, it is my hope that the importance of eye health is taken into consideration.

Finally, the Board and staff engaged in an excellent conversation regarding the accident driver's speed and whether the driver's failure to reduce his speed, as required by Greyhound policy and in keeping with State of California and FMCSA guidance, contributed to the crash or its severity. As staff pointed out, testing of crash avoidance technologies could not exactly duplicate the road conditions on the morning in question. However, it does seem clear that once the driver had crossed the solid line, entering into the gore area, a speed reduction of a few miles would not have provided him with significantly improved opportunity to avoid the obstacles in his path. Instead a more clearly marked gore area might have alerted the driver that, having bypassed his intended exit, it was too late to merge safely onto SR-85 and kept him from moving into the gore area at all. And, had the retroreflector been in place, the driver may have realized the impending crash in time to take evasive action to avoid or mitigate the impact.

Drivers of all abilities, ages and experience levels operate vehicles on our nation's roadways, and states must follow best practices in road design and maintenance to make sure that each driver and his or her passengers reach their destinations safely.

Acting Chairman Sumwalt and Member Hart joined in this statement on April 11, 2017.

Appendix A: Investigation

The National Transportation Safety Board (NTSB) received notification of this crash on January 19, 2016, and launched investigators to address highway, vehicle, and survival factors; motor carrier operations; human performance; and onboard recorders. The NTSB team also included staff from the Office of Research and Engineering.

The Federal Highway Administration, the Federal Motor Carrier Safety Administration, the California Highway Patrol, the Santa Clara Valley Transportation Authority, Greyhound Lines, Inc., and Trinity Industries, Inc., were parties to the investigation.

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